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Discover magical targets in midsummer evening skies

#194 JULY 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

TIME TO FIND PLUTO

How to observe the dwarf planet at its best for the year

NAKED BLACK HOLES

Why scientists are rethinking the idea of the event horizon

APOLLO 15's ANNIVERSARY

Relive the Moon buggy's first drive 50 years ago this month

IMAGING THE INVISIBLE

An introduction to capturing the hidden vistas of deep space

TOO MASSIVE FOR MARS

Are crewed missions to the Red Planet in jeopardy?

A DECADE OF DETAIL

One imager's project to capture our entire Galaxy

THE FINAL TOUCHDOWN

10 years ago this month: the Shuttle's last landing

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Welcome

Could black holes be stripped of their event horizons?

Get too close to a black hole and you'd reach a point of no return – the event horizon – past which you'd have to travel faster than the speed of light to escape its clutches. Or so the theory goes. As Colin Stuart explains in his feature this month, the event horizon is also a point of convenience which clothes over what we can't explain, how space and time cease to exist at the ultimate end point of a black hole, the singularity. Turn to **page 28** to read how new theories are suggesting ways in which black holes could exist without an event horizon, and how these theories can be tested.

As we look forward to the midsummer months without truly dark nights, it might be nice to imagine a place from which light cannot escape, but even in twilight skies there is much to observe. On **page 34**, Scott Levine takes us on a tour of the celestial beauties that are waiting to be discovered this month, when long evenings stretch from golden to blue before the first stars appear.

The planets will be on show this month too, with Saturn and Jupiter increasing in brightness, and a chance to see some fascinating passes of Jupiter's largest moons across the giant planet's face. Find more details in the Sky Guide from **page 43**, where there's also a challenge to locate tiny Pluto. Even at its brightest and best placed for the year this month, the dwarf planet is best located by capturing images, taking advantage of a camera's ability to reveal detail in the night sky that's too faint for our eyesight.

And Charlotte Daniels picks up this theme on **page 66**, where she explains how to capture deep-sky objects for first-time imagers.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 15 July.

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

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COVER MAIN IMAGE: BURADAKI/ISTOCK/GETTY IMAGES. THIS PAGE: NAEBLYS/ISTOCK/GETTY IMAGES, MIKEMAREEN/ISTOCK/GETTY IMAGES, NASA, @THESHED_PHOTOSTUDIO, CHARLOTTE DANIELS, J-P METSAVAINIO, NASA/SOFIA/LYNETTE COOK, BBC, ROUZBEH BIDSHAHRI

New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners

This month's contributors

Melissa Brobby

Amateur astronomer

"I've enjoyed writing about the Space Shuttle because it was a wonderful way to relive what was, for me, an exciting era in human spaceflight." **Melissa celebrates the 10th anniversary of the last Shuttle flight,** page 72

Scott Levine

Naked-eye observer

"Stargazing in summer is tough, but I love lying in the grass and watching the Summer Triangle arrive through the twilight and waiting for the night to fall." **Scott takes a twilight tour of the summer night sky,** page 34

Colin Stuart

Astronomer

"I love writing about black holes – even though we can't see them. They help light the way towards new and exciting theories in physics!" **Colin explores new research into naked black holes,** page 28

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/WMFHRQF/** to access this month's selection of exclusive Bonus Content

JULY HIGHLIGHTS

How collisions shaped the Solar System

Exclusive interview: planetary scientist Simone Marchi reveals the violent history of our cosmic neighbourhood

Watch *The Sky at Night: Mapping the Milky Way*

Maggie and Chris reveal how the European Space Agency's Gaia mission is producing a star map of our home Galaxy.

Access amazing astrophoto galleries

View this month's best images of the cosmos captured by the latest robotic probes, space telescopes and you.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

JUPITER IN A NEW LIGHT

The gas giant dazzles in these newly released infrared, visible light and ultraviolet images

GEMINI NORTH, HUBBLE SPACE TELESCOPE, 11 MAY 2021

Captured simultaneously by Hubble's Wide Field Camera 3 (WFC3) and the Gemini North infrared telescope on the summit of Mauna Kea in Hawaii, these images in different wavelengths reveal contrasting views of Jupiter's huge storms, cyclones and cloud bands.

The colossal Great Red Spot and its sidekick Red Spot Jr (Oval BA) almost vanish in infrared (left). Meanwhile, the long 'brown barge' streaking across the northern hemisphere – a series of cyclonic vortices 72,000km wide – stands out in visible (centre) and infrared light, but is barely visible in ultraviolet (right). And the four glowing 'hot spots' above the equator shine bright in infrared but are dark, cloud-free areas to the naked eye.

Interactive comparisons of these images are available at: noirlab.edu/public/images/comparisons

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA/ NASA/ESA/M.H. WONG AND I. DE PATER (UC BERKELEY) ET AL

MORE ONLINE

A gallery of these and more stunning space images

△ Star warps

HUBBLE SPACE TELESCOPE, 17 MAY 2021

Hundreds of galaxies and stars swarm the view in this wide-field image. So massive is galaxy cluster ACO S 295 that its gravity is bending, magnifying and stretching light from background galaxies, a phenomenon known as gravitational lensing. It can also cause replication, as seen in the string-like galaxy (top right).

◁ Message to Martians

PERSEVERANCE, 14 MAY 2021

The plaque attached to NASA's Mars Perseverance rover carries a laser-etched depiction of Earth and Mars, and a hidden Morse code message – 'Explore as One' – depicted in the Sun's rays. There are also three tiny microchips that hold the 11 million names that entered NASA's Send Your Name to Mars drive, plus the winning essay by the student who named the rover.

▽ Antique-lace spiral galaxy

HUBBLE SPACE TELESCOPE, 24 MAY 2021

This beauty, as delicate as antique lacework, is spiral galaxy NGC 5037, 150 million lightyears away in the constellation of Virgo. Just one small, faint member of the 150 or so members of the NGC 5044 galaxy group, its structures of gas and dust are showcased here in stunning detail thanks to Hubble's multi-wavelength Wide Field Camera 3.

△ We're nothing special

VERY LARGE TELESCOPE, 24 MAY 2021

The Milky Way may not be the result of a massive merger-triggered starburst, but is in fact a typical spiral galaxy that evolved peacefully over eons, new research suggests. Observations of the metal ratios of stars in Milky Way-like galaxies, such as UGC 10738 (pictured), with distinct thick and thin discs, revealed similar patterns of ancient stars in the thick disc and younger stars in the thin one. The researchers conclude that our Galaxy therefore is likely to have the same, unspectacular origin story and that it "didn't come about because of a gigantic mash-up".

ESA/HUBBLE & NASA/F. PACAUD/D. COE, NASA/JPL-CALTECH, ESA/HUBBLE & NASA/D. ROSARIO. ACKNOWLEDGEMENT: L. SHATZ, JESSE VAN DE SANDE/EUROPEAN SOUTHERN OBSERVATORY

BULLETIN

The newly discovered volcanic deposit around a fissure of the Cerberus Fossae system

NASA/JPL/MSSS/THE MURRAY LAB, CNSA X 2, KAVLI IPMU/AYA TSUBOI, NASA/ESA AND S. BACON STSCI

Could Mars still be volcanically active?

Dark ash appears to be the result of a recent – and explosive – eruption

Mars might not be such a dead planet after all, geologically speaking anyway. A newly discovered volcanic feature suggests there could have been activity on the surface in the past 50,000 years, according to a new study by researchers at the University of Arizona's Lunar and Planetary Laboratory and the Planetary Science Institute in Tucson, Arizona.

"This may be the youngest volcanic deposit yet documented on Mars," says Dr David Horvath, from the Planetary Science Institute, who led the study.

Recent orbital images of Elysium Planitia have revealed a 32km-long volcanic fissure surrounded by a 13km-wide deposit of dark material. Geologists believe it is the result of a pyroclastic eruption, where gases in the molten rock cause it to violently explode, rather than become the slow-flowing magma that spread across most of the Red Planet.

Most volcanic activity on Mars took place 3 to 4 billion years ago. Until now, there was no evidence to indicate Mars could still be volcanically active.

"This feature overlies the surrounding lava flows and appears to be a relatively fresh and thin deposit of ash and rock, representing a different style of eruption than previously identified pyroclastic features," says Horvath. "This eruption could have spewed ash as high as 6 miles [10km] into Mars's atmosphere. It is possible that these sorts of deposits were more common but have been eroded or buried."

NASA's InSight lander, which is currently listening out for marsquakes, has measured two seismic events coming from the region around the fissure, indicating there is volcanic activity beneath the surface. The region is also only 10km away from Mars's youngest large crater, suggesting a recent impact could have trigged the activity.

"All the data seems to be telling the same story," says Associate Professor Jeffrey Andrews-Hanna, from the University of Arizona. "Mars isn't dead."

https://news.arizona.edu

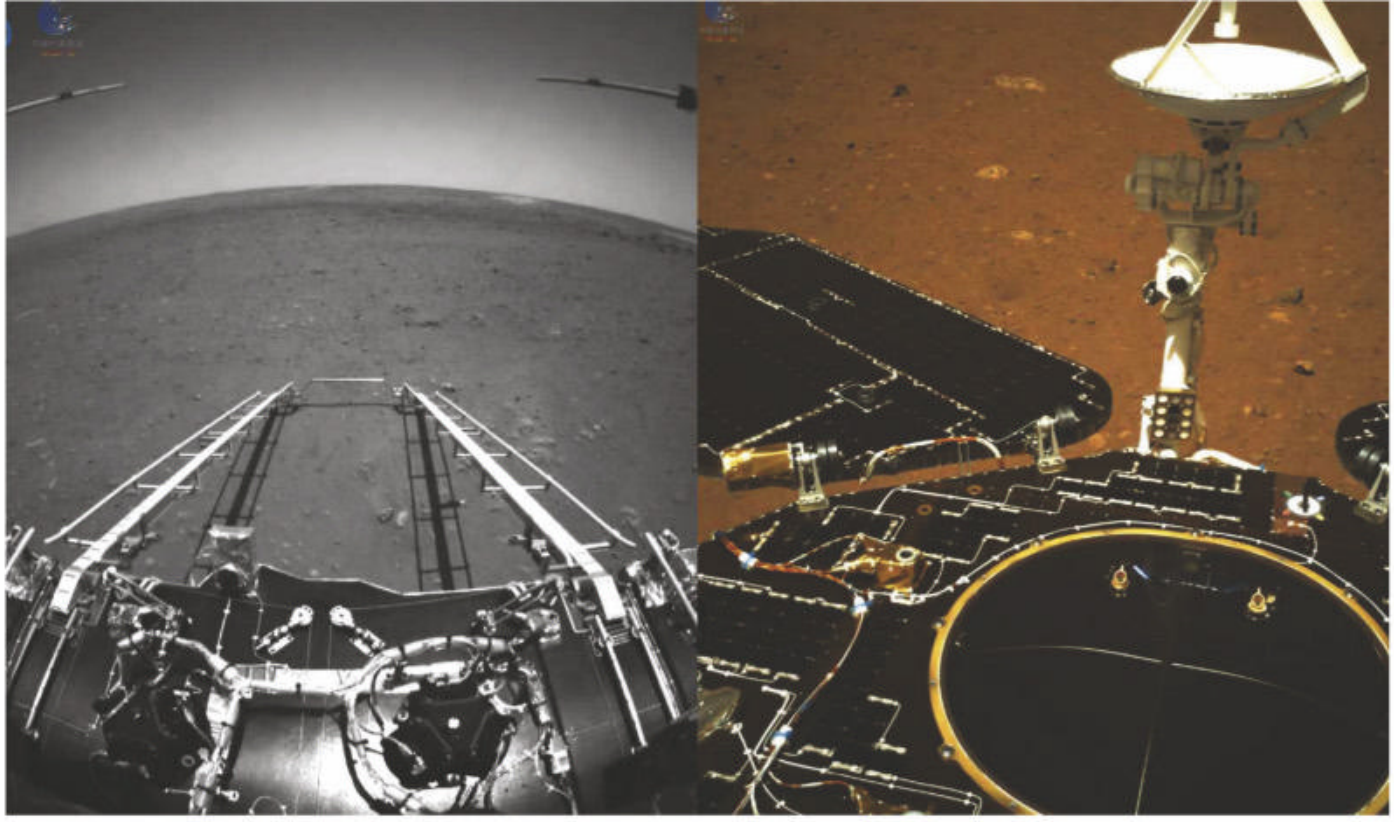
Comment

by Chris Lintott

With four active robots on the surface, and a fleet of orbiting spacecraft, the Red Planet is coming under scrutiny like never before. The most exciting results come when different observations can be tied together. Volcanic activity – like the kind that the team found using data from NASA's Mars Reconnaissance Orbiter – might fit in with the observation from the Curiosity rover of 'burps' of methane, and its possible presence in the atmosphere.

Methane, which might be produced by volcanic activity or maybe just by biological processes, is the primary target for the European Space Agency's Trace Gas Orbiter, though it has so far drawn a blank.

Chris Lintott co-presents *The Sky at Night*



▲ Left: the plain of Utopia Planitia; Right: the unfolded solar panels and communications antenna

China's Martian touch-down

The nation's first ever landing on another planet

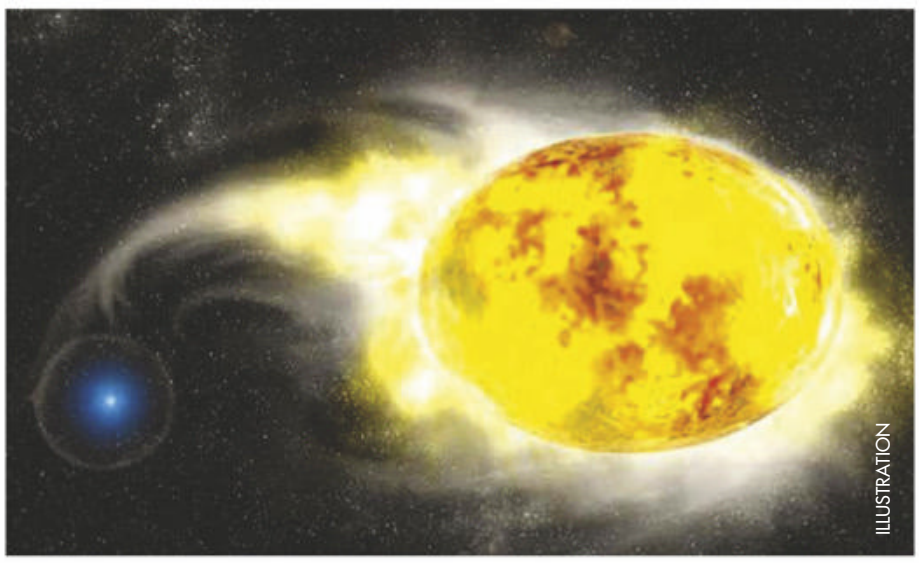
The Chinese National Space Administration has successfully landed its Zhurong rover on the surface of Mars on 15 May, marking the nation's first ever landing on another planet.

The rover was released from the Tianwen-1 spacecraft, which has been in orbit around Mars since February 2021, before touching down in Utopia Planitia, a region which is thought to be the bed of an ancient sea. As well as a suite of cameras and spectrometers, Zhurong carries a ground-penetrating radar that will look beneath the surface to search for pockets of water and ice, helping to uncover the history of water in the region.

"Landing safely on Mars is a huge challenge, especially for China's first soft landing attempt," says Long Xia, from the China University of Geosciences. "But it is a necessary step for Mars and deep-space exploration."

www.cnsa.gov.cn/english

Hydrogen-free supernova confuses astronomers



▲ A blue companion star taking hydrogen from a yellow supergiant

A supernova has confounded astronomers by being too yellow. Astronomers noticed the star's jaundiced appearance after tracking down an image of its host galaxy, NGC 4666, taken two-and-a-half years ago by the Hubble Space Telescope.

Normally, the yellow colour is caused by a layer of cool hydrogen, yet observations taken after the star went supernova show no signs of the gas.

"We haven't seen this scenario before," says Charles Kilpatrick from Northwestern University, who led the investigation. "If a star explodes without hydrogen, it should be extremely blue – really, really hot. It's almost impossible for a star to be this cool without having hydrogen in its outer layer."

A few months after the supernova, its shockwave collided with clouds of hydrogen, suggesting the star was throwing off its outer layers in the months leading up to the explosion.

"This star's discovery provides some of the most direct evidence ever found that stars experience catastrophic eruptions, which cause them to lose mass before an explosion," says Kilpatrick. "If the star was having these eruptions, then it likely expelled hydrogen several decades before it exploded."

Alternately, a companion star could have syphoned the gas away, but astronomers won't be able to hunt for such a star until the supernova has dimmed, which could take a decade.

www.northwestern.edu

NEWS IN BRIEF

Shrinking super-Earths

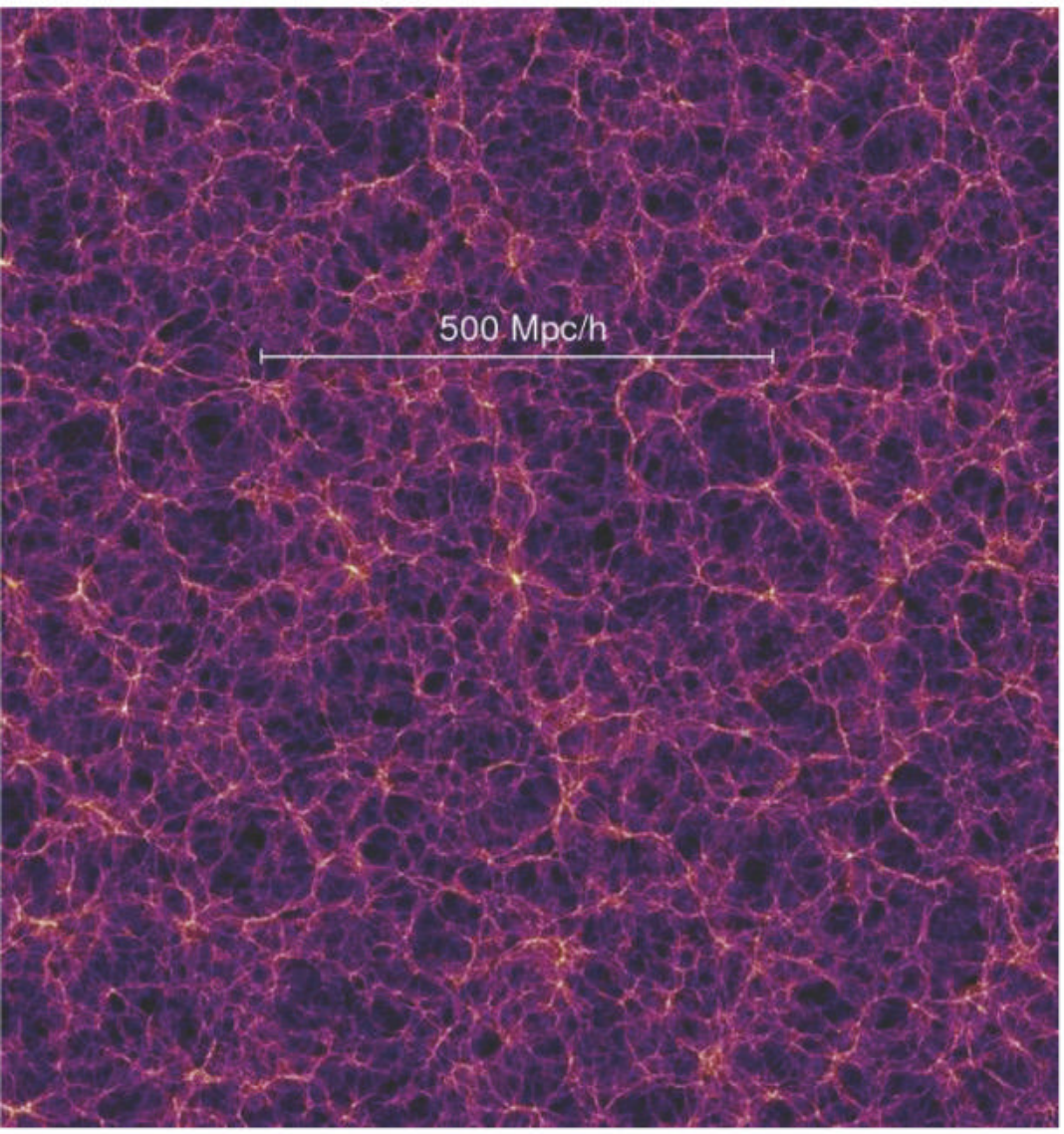
Astronomers may have discovered why there are so few planets with radii between 1.5 and 2 times that of Earth – they're shrinking. A recent study of the few known planets which fall into that bracket found they get smaller with age, suggesting the planets are losing their atmospheres over time.

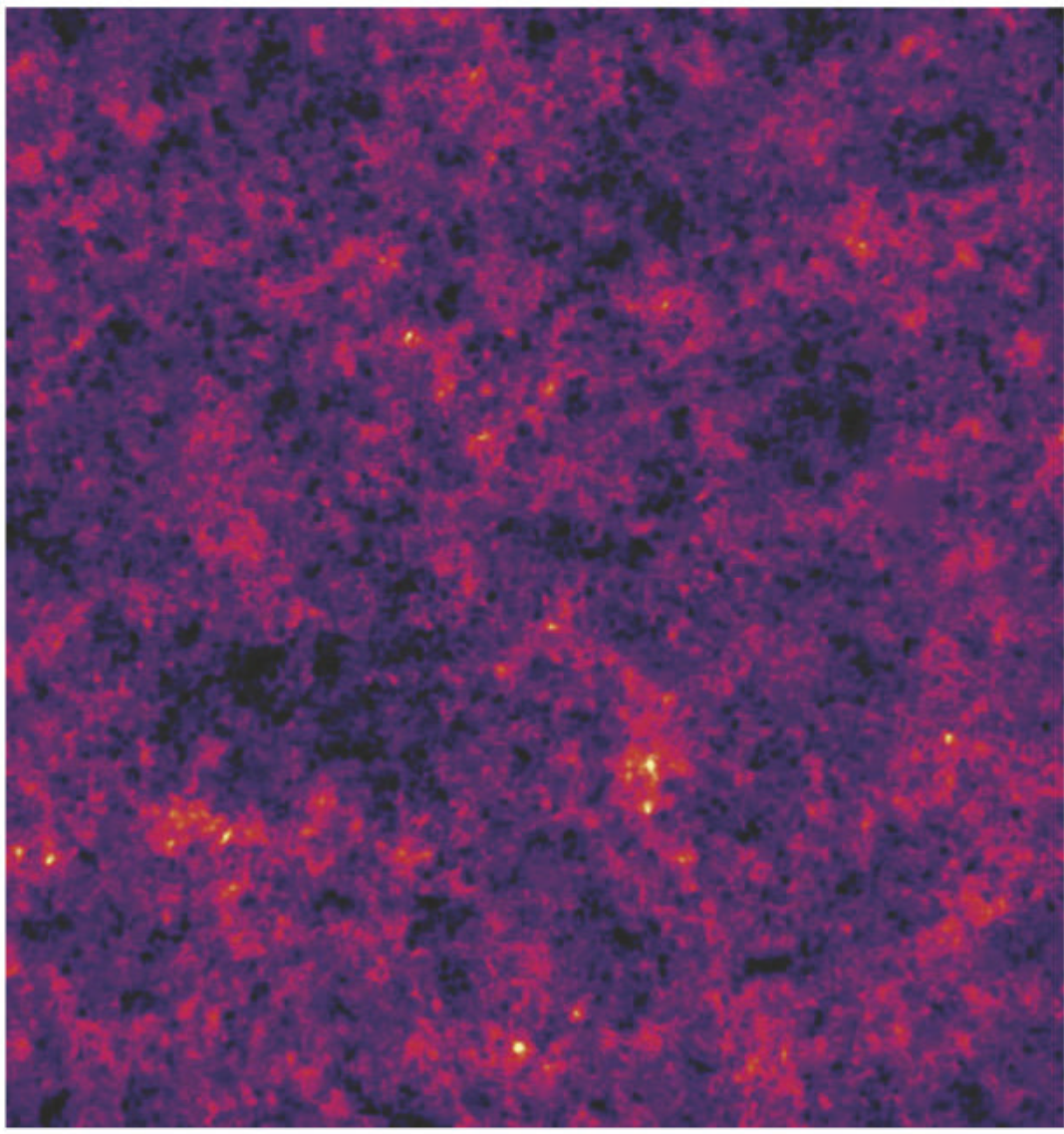
Stolen stars

A recently completed survey of giant red stars has found that several of the oldest stars in our Galaxy originally belonged to a satellite galaxy called Gaia-Enceladus, which collided with the Milky Way billions of years ago. A team from the University of Birmingham looked at the vibrations of the stellar surface to accurately estimate the star's age.

Mg-rich ice giants

The oceans of ice giants Neptune and Uranus could have very different chemical properties to those of Earth. A recent set of experiments found that the high pressure would cause elements like magnesium to dissolve out of the rock more readily, affecting how heat escapes from the planet's core.





▲ **The Dark Energy Survey map (right) suggests a more even spread of dark matter than in the Cosmic Microwave Background map (left)**

SPRINGEL ET AL, DARK ENERGY SURVEY, NASA/JPL-CALTECH/MSSS

New dark matter map shows unexpected smoothness

Largest ever map of the mysterious force hints at gaps in our current predictions

The Universe is far less 'clumpy' than it should be, according to results gleaned from the Dark Energy Survey's (DES) first three years of data. The observations disagree with the current best theories by cosmologists of how the Universe should look, given the structure of the early Universe we see in the Cosmic Microwave Background (CMB).

"It would be very exciting to find contradictions between galaxy surveys like DES and analyses of the CMB, as they would provide hints of new physics," says Pablo Lemos from University College London, who was part of the analysis team. "This observed difference in the clustering of matter could be one such contradition, but we will need more data to confirm it."

The Dark Energy Survey is a six-year project to map out matter within the Universe as a way to investigate dark energy – the mysterious force which astronomers have seen driving galaxies apart, but which cosmologists struggle to explain. Despite making up around 70 per cent of the Universe, dark energy can't be measured directly. Instead, astronomers map out the distribution of matter over the Universe, then look at this to see what effect dark energy has had on it.

The team have now processed the first three years of observations of 226 million galaxies over 5,000 square degrees of sky. As well as measuring visible matter by looking at the positions of the galaxies they could see, the team also hunted for invisible dark matter using gravitational lensing, searching for light from distant sources in the Universe which has been distorted by massive objects closer to us.

With this Dark Energy Survey map in hand, the cosmologists could then compare it to their models of how the Universe should look. These simulations are based on observations of the Cosmic Microwave Background, very early light in the Universe, from the Planck space observatory, to which is applied our understanding of how the cosmos has grown over time – including the effect of dark energy.

The CMB simulations create a spider web of galaxies clustered within strands of dark matter, with huge voids in between, while in the actual observations by DES dark matter is a lot more evenly, or smoothly, distributed. The difference is only a few per cent, but it is a clear pointer that our current understanding of how the Universe has grown is not yet complete.
https://ucl.ac.uk

▸ See page 15 to read about a new survey that will provide more detail on the effects of dark matter on distant galaxies

Ingenuity gets an extended run

The Ingenuity Mars Helicopter has been a huge success over the last month, and so NASA has decided to extend its mission alongside the Perseverance rover for one more flight.

On 7 May, Ingenuity undertook its fifth – and originally meant to be final – flight, travelling 129m one way, away from Perseverance. It performed so well that NASA added a sixth flight to its plan, which is due to take place in the week starting on 31 May. This excursion will be the most difficult that Ingenuity has attempted, helping push the limits of the technology to better understand what future rotorcraft probes could be capable of. During this sixth flight it will travel 150m, staying aloft for over two minutes as it takes colour spectroscopic pictures of the surrounding terrain.

It will then attempt to land in an area which it didn't survey in any of its previous flights, as it did before all its previous landings.

NEWS IN BRIEF

Uncontrolled rocket deorbits

A Chinese Long March 5B rocket made an uncontrolled re-entry on 8 May. Though it came down in the Indian Ocean there was no way to control its crash site, leading many in the space community, including NASA administrator Bill Nelson, to question if China was "failing to meet responsible standards regarding their space debris".

OSIRIS-Rex heads home

NASA spacecraft OSIRIS-REx left asteroid Bennu on 10 May. The spacecraft has been at Bennu since 2018, during which time it took a sample of the space rock that it is now returning to Earth. It is expected back on 24 September 2023.

Interstellar hum

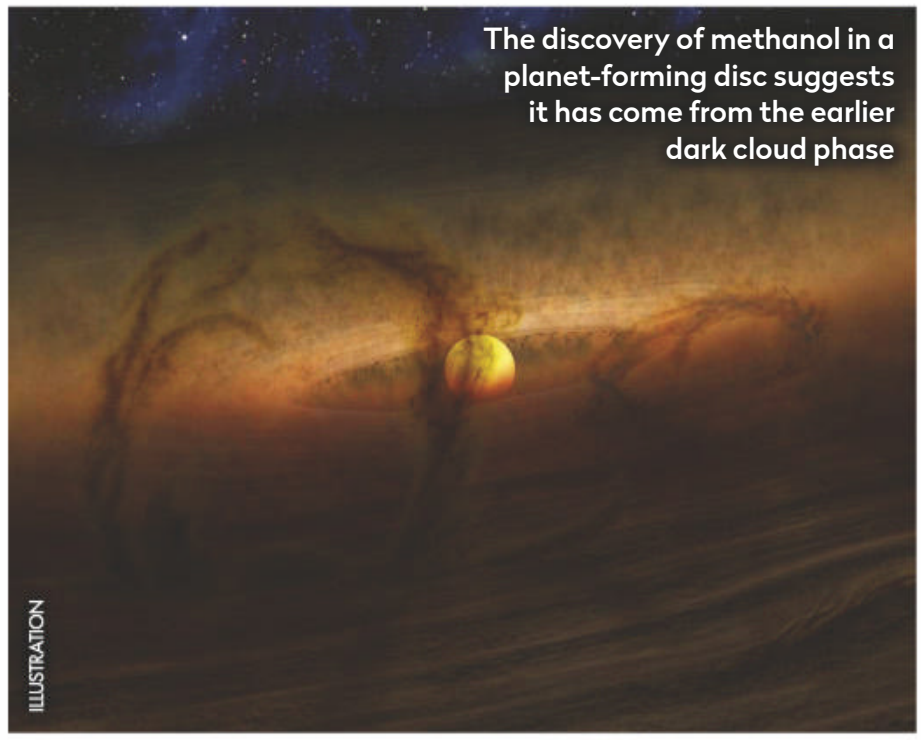
NASA's Voyager 1, which has been sailing through space beyond the Sun's protective magnetic bubble since 2012, has detected a faint hum in the interstellar gas. The signal is a very faint, monotonous vibration in the plasma that fills the space between our star and its neighbours.

CNSA, NASA/JPL-CALTECH, HIE/COURTESY OF PERFECT CIRCLE PV, DESI COLLABORATION/ DESI LEGACY IMAGING SURVEYS/LBNL/DOE & KPNO/CTIO/NOIRLAB/NSF/AURA/UNWISE

BULLETIN

Ingredient of life found in planet nursery

Organic compound must have been present in a star-forming nebula



The discovery of methanol in a planet-forming disc suggests it has come from the earlier dark cloud phase

ILLUSTRATION

Methanol, one of the chemical building blocks of life, has been discovered in the planet-forming disc around a young star by the Atacama Large Millimeter/Submillimeter Array (ALMA). The chemical can't have formed in the disc, meaning it must have been present in the initial cloud that formed both the star and its planetary system.

"This is a very exciting and surprising result. While methanol has been detected in warm young discs, because of the nature of this disc this is the first clear observational evidence that complex organic molecules can be 'inherited' from the earlier cold dark cloud phase," says Alice Booth from Leiden University in the Netherlands, who led the study.

The discovery helps build an understanding of how these life-creating chemicals come to be on planets like Earth, and the team will now look for more complex prebiotic chemicals.

www.almaobservatory.org

UK space industry's rapid growth

Space business is booming in the UK, as the latest survey showed that the number of people employed in the industry rose by 3,000 in a single year between 2018 and 2019. That number is only set to rise as the government has announced its support of two new UK space initiatives.

ILLUSTRATION

▲ **The designs for Space Hub Sutherland are moving forward; it will eventually become a launch site for 12 satellites a year**

In May, UK company Surrey Satellite Technology Limited (SSTL) announced that it was leading several other UK-based companies in looking into the plausibility of setting up a lunar communications and navigation service. It is one of two investigations into building such infrastructure commissioned by the European Space Agency (ESA) to help support the growing number of Moon missions expected over the next few decades.

Then in Scotland, on 26 May ground investigations began on the proposed site of a satellite launch site in Sutherland, which will help inform the final design of the facility. The team are examining the soil and bedrock conditions, as well investigating the wildlife and landscape to ensure the minimum environmental impact.

bit.ly/2W6A1v7

Project to create 3D map of the Universe begins

A five-year mission to take spectroscopic measurements of around 30 million galaxies using the Dark Energy Spectroscopic Instrument (DESI) in Tucson, Arizona began on 17 May. The telescope is made up of 5,000 individual fibres, each of which can be pointed towards a specific galaxy allowing thousands of simultaneous measurements. It can cover an object as large as the 3°–long Andromeda Galaxy in one go – as shown here, with each blue circle showing the area covered by one fibre. The data will be used to measure how far away these galaxies are, creating a 3D map that will help investigate the dark matter that appears to be accelerating the Universe's expansion.

Our experts examine the hottest new research

CUTTING EDGE

ILLUSTRATION

The payload of a human Mars mission, including provisions and equipment, will make it tricky to land unless the Martian surface is prepared

Could humans be too heavy to land on Mars?

The engine needed to land on Mars could blast a hole in the surface instead

We've all seen the movie. The first human mission to Mars descends towards the ochre-coloured surface on a roaring column of rocket thrust. After touching down, the astronauts clamber down the ladder, plant a flag in the soil and snap some photos of their footprints.

We've done it on the Moon, so why not Mars? Aside from all the hazards to the astronauts during the months-long interplanetary flight to Mars (such as exposure to cosmic radiation), the landing itself could actually be pretty problematic. Philip Metzger and his colleagues at NASA's Kennedy Space Center in Florida are raising the alarm over an issue that could potentially be very significant for human missions, but has received barely any consideration until now.

The problem is that a landing craft carrying the crew of astronauts – and much of the provisions and equipment needed to keep them alive on Mars for many months – would be heavy. And that means it needs a powerful rocket motor to touch down safely.

For the Apollo Moon landings, the descent motor mostly blasted dust horizontally away across the surface, and no visible crater was gouged out by the rocket. This is because over billions of years, the lunar surface has become compacted, and the vacuum conditions allow the rocket exhaust to disperse.

Surface pressures

However, the situation is very different on Mars. Its surface material is much looser, and the atmospheric pressure serves to keep the engine plume focused on one small spot, allowing it to blast much deeper. This means, Metzger says, that the descent engine of a large Martian lander would blow loose rocks across the surface at high speeds up to a kilometre away – presenting a risk to the crew habitats or other equipment that the mission needs to touch down near. Not only that, but as a blast crater begins to form, the inclined crater walls will serve to deflect fast-moving lumps of rock back upwards into the underside of the lander, potentially causing damage. Even worse, if a sufficiently narrow and deep crater forms directly beneath the rocket nozzle, when the engine cuts off after landing the crater could then collapse into itself, leaving the lander in a precarious position on unstable ground.

> ***"An advance robotic mission is needed to level off and clear the target zone of debris, and then stabilise the surface into a landing pad"***

The solution will be to make sure a suitable landing site has already been prepared before the human mission arrives. An advance robotic mission would be needed to level off and clear the target zone of debris, and then stabilise the surface into a resistant landing pad by cementation, or perhaps by fusing the mineral grains together with a powerful microwave beam.

The risks are so great, says Metzger's team, that we should not even attempt human landings on Mars until we have reliably demonstrated the automated construction of landing pads using robots. They argue that the best place to practise and perfect this critical process is right on our doorstep, on the Moon.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *ISRU Implications for Lunar and Martian Plume Effects* by Philip T Metzger et al.
Read it online at: https://arxiv.org/abs/2104.06248

NASA, ESA–D. DUCROS/2013

Star formation comes in waves

Gaia data has revealed new stars bursting into life across our local Galactic neighbourhood

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

When our far distant ancestors first looked up at the stars to create hand-drawn charts of the constellations, they began a process of exploration that has grown ever more sophisticated. Nowadays, the three-dimensional data from missions like the European Space Agency's Gaia, provides a new key to these old maps.

This month's paper sifts through Gaia's list of nearby stars, looking for the youngest of them. Young stars are important because studying them can reveal the conditions in which they formed, and help us understand what's really going on deep in places like the Orion Nebula. The fact that most young stars are found living gregarious lives as part of clusters or loose associations, for example, tells us that such stellar nurseries form multiple stars – and perhaps multiple generations of stars, with each wave of star formation triggering the next.

To see if evidence for this process is hidden in our local clusters, the team behind this month's paper start with five million of the closest stars. For each, they look at its properties, and train an algorithm to calculate the probability it has a particular age. The task is difficult, as less than one per cent of stars in our part of the Milky Way are truly young, born in the last 50 million years, but testing on model data shows that they do a good enough job. Once young stars are spotted, a second algorithm can assign them to 27 clusters.

A sense of scale

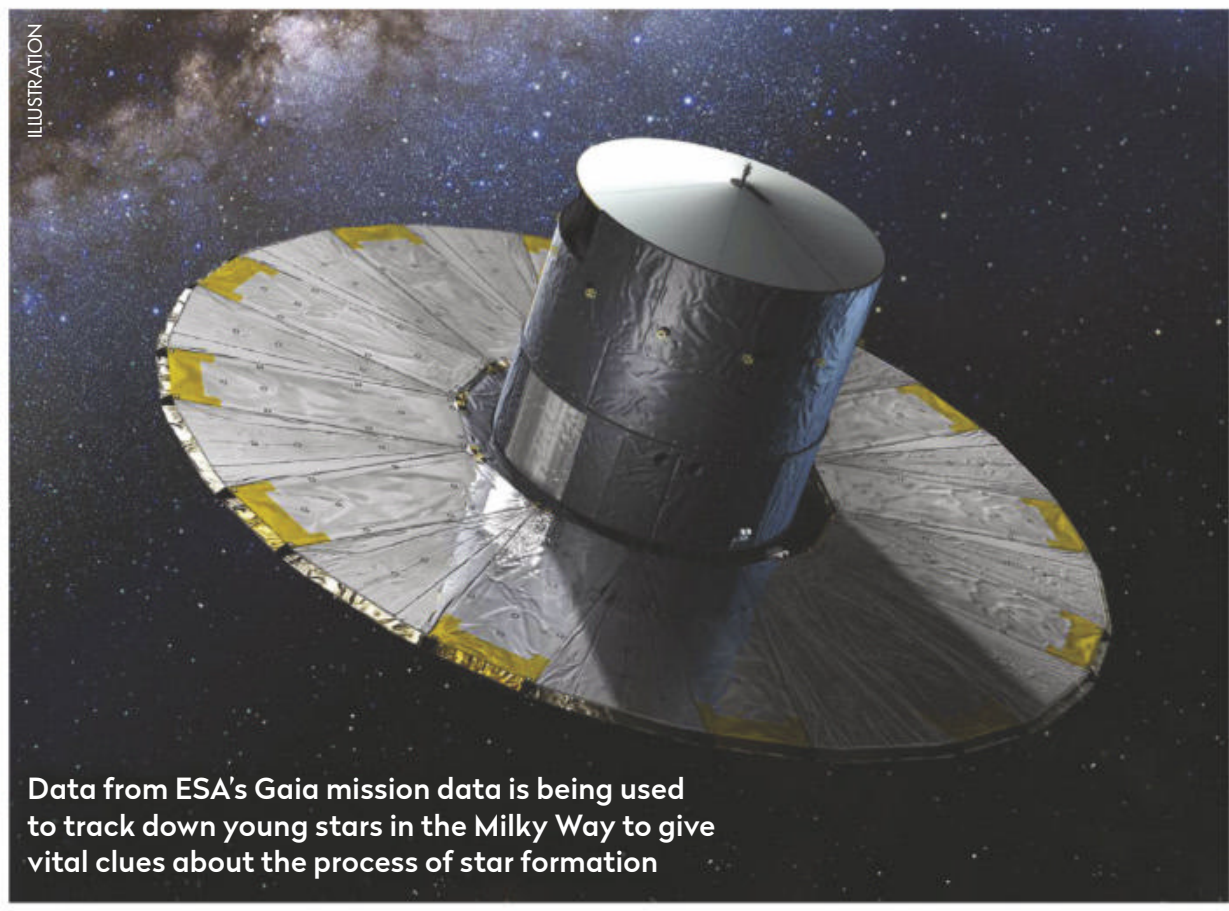
These clusters range in scale from well-known objects such as the Pleiades, to the relatively obscure (ASCC 123 anyone?), and while some have only a few dozen stars the mighty Sco-Cen group counts more than seven thousand of the stars in the data as members. This largest cluster is interesting because the properties of its members depend on their position in the cluster, younger stars being further out. This makes sense if you think of star formation as a Mexican Wave proceeding through a nebula, each round triggered by the previous one next door.

The authors even calculate the speed with which star formation moves; just over 4km/s, with the oldest stars belonging to a newly identified grouping called the Libra–Centaurus arc. Stars, it seems, formed here and then the violent winds associated with their births stirred nearby gas, causing more fireworks.

There are also signs that things happen on larger scales. Smaller, low density groups identified in the constellations of Monoceros, Vela, Cepheus and Carina all seem to have evolved at the same time, suggesting that the physics that controls the behaviour of turbulent and star-forming gas can affect whole regions at once. The process that produces stars in these relative backwaters may be very different, perhaps requiring a kick from a conveniently placed nearby supernova to get going.

"The authors even calculate the speed with which star formation moves: just 4km/s, with the oldest stars belonging to a newly identified grouping"

The complex story of our neighbouring stars – and of the Sun's role in this tale – will continue to unwind as astronomers dig into the Gaia data. In doing so, they're just adding to the long history of mapping our Universe.



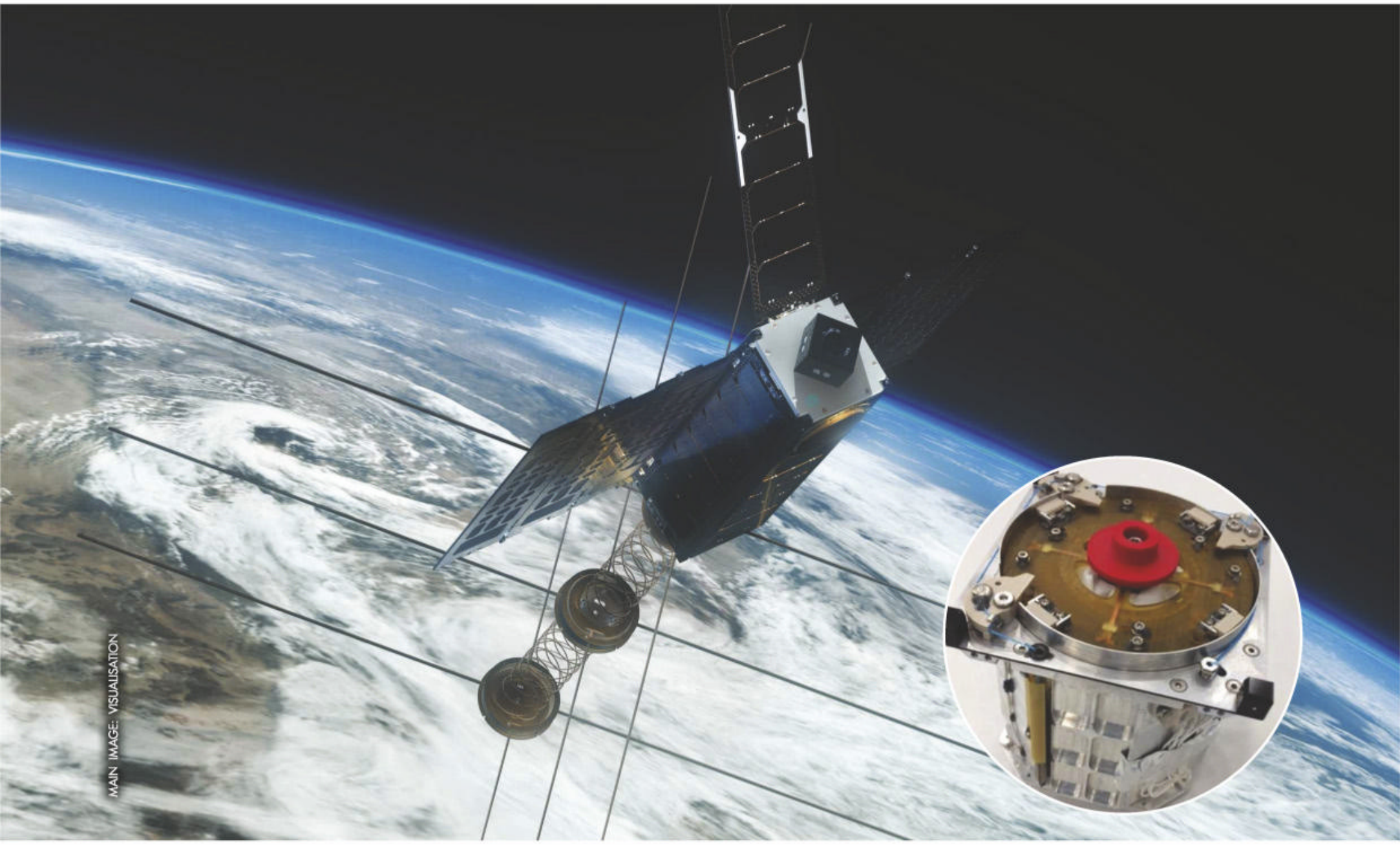
ILLUSTRATION

Data from ESA's Gaia mission data is being used to track down young stars in the Milky Way to give vital clues about the process of star formation

Chris Lintott was reading... *Stars with photometrically young Gaia luminosities around the Solar System (SPYGLASS) I: Mapping young stellar structures and their star formation histories* by Ronan Kerr et al.
Read it online at: https://arxiv.org/abs/2105.09338

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



In the June episode of *The Sky at Night*, **Sean Sutcliffe** spoke about what it's like working in the UK spaceflight industry

▲ Main image: the light-weight deployable antenna technology used on low-Earth satellites could be adapted to map ice on Mars

Inset: a stowed antenna fits in a box that is just 10cm cubed

ROBERT LINSDELL, SETI INSTITUTE

The proliferation of mega-constellations of satellites has attracted plenty of concern, whether from the fear of a chain reaction resulting in catastrophic levels of space debris or the effect on astronomy from light pollution. While these are very real problems, the increasing use of low-Earth orbit satellites has also brought a range of benefits.

The dilemma facing mission designers is that in order to get the performance they want they need as large an antenna as possible to get the gain or resolution required. However, that takes up too much space and is very heavy. One solution that we've been developing are deployable antennas, which as well as saving space are also lower mass. When stowed, the antenna fits in a box that's about 10cm cubed. When it folds out and is fully deployed, the antenna has a length of 60cm and spans 90cm.

We have a satellite which will monitor shipping that's due to launch later this year as well as three other antennas already in space, launched in the last year, helping to improve among other things logistics, wildlife monitoring and agriculture. We have also launched a deployable boom as part of a mission to test debris removal, making a contribution in the search for solutions to this looming problem.

Mapping ice on Mars

Alongside these immediately practical applications we also contribute to the broader British spaceflight initiative. A recent project we have looked at addresses a future mission to map ice on Mars. For this we can take a deployable antenna we are

Sean Sutcliffe is the CEO of Oxford Space Systems

developing to take radar observations monitoring flooding on Earth, and we can determine what it would take to adapt it for a Mars mission. Radar has a lot of benefits – such as being able to observe day and night, regardless of the cloud cover – that would be just as useful at Mars.

Apart from the obvious lure of being involved in space exploration, why are the people in the UK space industry so passionate about what they do? I think on the one hand it is due to the sheer difficulty of the job in hand. The need for equipment to survive the harsh conditions of a launch and space environment while guaranteeing deployment of an intricate and light-weight antenna is a terrific engineering challenge – and we all like to succeed in the face of a tough task.

The other aspect is the thrill of doing something new. The teams are bringing new ideas to space, whether it is the use of composite materials for backing structure ribs, origami engineering to create compact structures, or metal mesh knitting technology to provide high performance antenna surfaces. This requires a blend of openness to new ideas, working in diverse interdisciplinary teams and dedication. This level of enthusiasm, whether it is displayed in the office or on a Zoom call, makes it an honour and a pleasure to be part of.

Looking back: The Sky at Night

20 July 1977

On the 20 July 1977 episode, Patrick took a look at a new British telescope being built in Hawaii, which we now know as the United Kingdom Infrared Telescope (UKIRT). Construction began in 1975, but it wasn't until 1979 that the telescope's 3.8m-wide primary mirror saw first light.

▲ **One of the largest infrared telescopes in the world, the UKIRT telescope is located on top of Mauna Kea**

Although ending up in Hawaii, the telescope's optics were made in Newcastle while much of its infrastructure was created in Sheffield. Unfortunately, neither location is well known for the cloud-free skies astronomy demands, and so the final telescope was constructed in Hawaii. As the infrared light that the telescope would look for is rapidly absorbed by the atmosphere, it was built on top of Mauna Kea at an elevation of 4,200m, above most of Earth's atmosphere.

UKIRT was and remains one of the largest infrared telescopes in the world, but it won't be much longer. As part of efforts to better respect the status of Mauna Kea as a sacred site to Native Hawaiians, the scope is due to be decommissioned as soon as construction is complete on the Thirty Meter telescope. UKIRT will be dismantled and the site returned to the way it was before the scope was built.

ET and the BBC

Could we be the only planet in the Universe to support life, or might there be some form of life – be it extra-terrestrial sentience or microorganisms and bacteria – to be found even within our own Galaxy? In this one-hour special, Maggie and Chris delve into the archives and take a look at how the BBC has reported the search for life in the Universe over six decades.

BBC Four, **11 July**, 10pm (first repeat BBC Four, **15 July,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **The Allen Telescope Array in California is the first telescope designed specifically to search for extra-terrestrial intelligence**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize:
four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

A new hobby in lockdown

Around the time of the first lockdown last year I turned 18 and the situation lent itself well to waking up at lunchtime and going to bed at dawn. This, along with the hours spent in the garden longing to leave the house, created the perfect conditions for astrophotography.

I discovered my love for it about nine months ago, and have made use of some of my dad's old camera equipment (plus occasional purchases) to catch as many targets as possible. Here are images of the Andromeda Galaxy, the Heart and Rosette Nebulae, captured using minimal kit; a Canon EOS 7D and 100–400mm lens on a Sky-Watcher Star Adventurer mount. The images were processed in DeepSkyStacker and Adobe Photoshop. Hopefully they show what can be achieved with minimal gear and little experience. **Ted O'Connor, Edinburgh**

What a great skill to have learnt over lockdown, Ted. Your photos show some really clean captures with a lovely handling of detail! ***– Ed***



▲ From left: Ted's impressive images of the Andromeda Galaxy and the Heart and Rosette Nebulae

Tweet

Astro Mike
@xRMMike • May 26
Tonight's super duper BIG flower Moon over Longleat, Wiltshire
Canon 90D, Sigma 150-600
#SuperMoon #FullMoon @CanonUKandIE
@skyatnightmag

Unseen stars?

I find it truly awe-inspiring that when I look at stars or galaxies, the light I am seeing has been travelling for hundreds, if not thousands, of years until it reaches Earth, and indeed my retina. What I don't understand, however, is why 'new' stars and galaxies are not appearing in the night sky as the previously unseen light from them finally reaches Earth.
Derek Summers, Cardiff

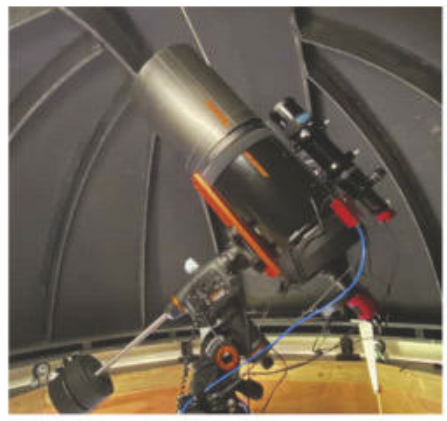
Lawful enquiry

Your recent article 'Where to Stargaze in England' (April issue, page 66) highlighted new Dark Sky Parks at Fewston and Thruscross Reservoirs in North Yorkshire, and I thought you might be interested to read about my first experience of stargazing in that area.

I had spent a rewarding evening in a remote lay-by on an unlit, deserted, country road making the most of the absence of light pollution, but the cold weather eventually got the better of me so I decided to pack up. As I was loading my tripod and telescope into the car another vehicle pulled sharply into the lay-by. Closer inspection revealed it to be a police car, with two uniformed officers staring at me from the interior. They asked what I was doing in the lay-by, and I gave the only truthful answer that I could give: "Well, officers, I was erm... watching the moons of Jupiter!"

Fortunately, they then noticed my red head torch and telescope so they laughed and, thankfully, no handcuffs were locked onto my wrists.

They then explained that the lay-by had been used by local criminals as a base when carrying out burglaries at nearby farms, so they were keeping an eye on it. Needless to say, I never used that lay-by again.
Bob Cullingworth, Grasmere, Cumbria



▲ **With its 3m-dome in place, Laurence's new observatory is ready for him to enjoy many nights of stargazing**

Dome at home

I thought I'd share with you the observatory I've just finished building recently. It has a 3m-diameter dome and is located in my backyard. The observatory is inspired by and based on a design in *BBC Sky at Night Magazine's* special issue, *The Big Book of DIY Astronomy Projects*

Laurence McCarthy, via email

Space jets

I enjoyed reading the May 2021 issue of *BBC Sky at* ▸

ON FACEBOOK

WE ASKED: Summer means shorter nights. What are your tips for summer stargazing?

Carol Miller I cope by making use of the beautiful sunrises and sunsets over Lanivet, Cornwall. I am an amateur photographer so I almost always have a camera on me. If I feel in the mood I will pop out during the hours of darkness and use binoculars to scan the sky. By doing this I have become more interested in constellations, nebulae and star clusters and, of course, I can always watch the Moon, depending on its phase. So, not all is lost for an amateur astronomer during the summer months.

Craig Roberts Summer means planets :)

Mick Cassidy All year round my Dobsonian goes out but yes, the shorter brighter nights do cut down on observing objects. The Milky Way and noctilucent clouds come to the fore, which makes a nice change.

Simon Whitfield Summer astronomy could also involve using solar film, a Herschel wedge or various solar spectrum filters (Ha, CaK, CaH, Sodium, etc) to study the Sun; it is a star after all!

Kriss Jupiter. And we still have the Moon plus noctilucent clouds to look out for.

Brian Smale Post-processing astrophotos taken in the winter.

Steve Walker I always look forward to the Perseids.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher 150 Dobsonian. How and when should I clean the primary mirror?

TONY WRIGHT

▲ **If you need to clean your telescope mirror proceed with extreme caution**

The key to cleaning a telescope mirror is don't, unless it is absolutely necessary! You need a lot of contamination for it to have any effect on the view.

If and when the time does come, perhaps because of a dead insect or similar issue contaminating the surface, then proceed carefully.

Remove the mirror from its mirror cell and soak it in a plastic bowl with tepid water and a few drops of washing-up liquid for about five minutes to loosen the dust and other particles. Then remove the mirror and stand it on its side safely. Replenish the water in the bowl with fresh water and a few drops of washing up liquid, then carefully drag pieces of well-soaked cotton wool across the mirror surface under their own weight in a series of strokes, replacing the cotton wool with each stroke.

Finally, rinse the mirror surface with distilled water and rest it, supported at a steep angle, on a fresh towel and leave it to dry. Reassemble and collimate. You can watch a video of the whole process at **http://bit.ly/MirrorClean** if you need more help.

Steve's top tip

What is a dioptre in binoculars?

It is quite normal for your eyes to focus slightly differently from one another, but this only becomes an issue when using binoculars. Most binoculars have a single focusing knob that adjusts the focus of both barrels, so manufacturers include a means of compensating for the difference between your eyes by incorporating a small amount of individual focus adjustment in one of the eyepieces – known as the dioptre adjustment.

To set the dioptre for your eyes, cover the barrel that has the dioptre adjustment and focus the other one on a distant object. Remove the cover and adjust the dioptre while observing the same object until the focus is correct for both of your eyes.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE IMMEDIATE MEDIA Co

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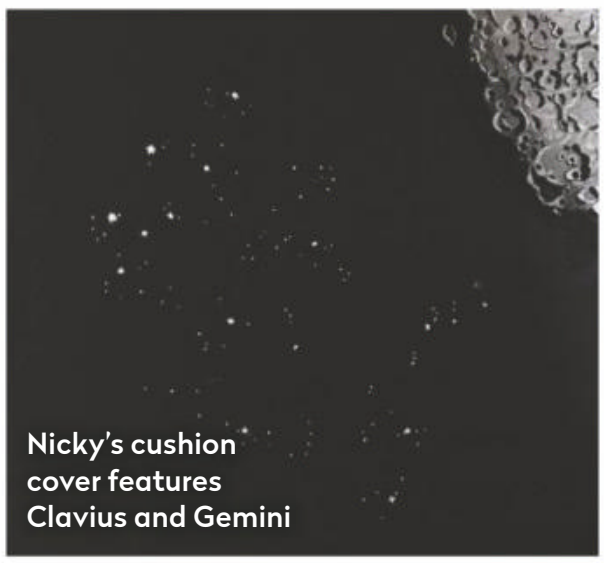
▸ *Night Magazine*, particularly two stories about black holes – PJ352-15 and M87 (pages 11 and 15 respectively). I understand that such objects are known to have very powerful relativistic jets full of ionised matter travelling at nearly the speed of light, which stretch beyond the boundaries of their host galaxies. I wonder if, in theory, such jets can be used for intergalactic space travel?
Slava Gromlyuk, Essex

Birthday treat

I made this cushion cover (below) showing a doleful lunar crater Clavius looking away from Gemini. It's hand and machine embroidered and was done for a friend's birthday. I hope they'll like it!
Nicky Robertson, via email



Nicky's cushion cover features Clavius and Gemini

Instagram

gtpics123 • 26 May

Quick edit and collage of the flower supermoon tonight as it rises, through some clouds and trees (I like how some of the branches look like flowers over the orb). #astronomyireland #astrophotography #superflowermoon #wecannotseetheeclipse #astronomy @bbcskyatnightmagazine @canoneurope @nasa @europeanspaceagency

SOCIETY IN FOCUS

Clydesdale Astronomical Society (CAS) formed in June 2006 after our first chairman came back from observing the solar eclipse in Turkey. We are a small, friendly society whose members range from beginners to advanced. Like many other societies, we had to adapt to keep members' spirits up during the COVID-19 outbreak. We used to meet regularly at the Bankhall, Climpy Road, South Lanarkshire on the second Monday of every month, but these meetings had to be put on hold. Since May last year we've held talks via Zoom, which has allowed us to gain new members and associate members from further afield.

Some speakers have kindly allowed us to record Zoom meetings for our YouTube channel, which enables us to have access to those who live further away. Once it is safe to meet in person again, we will have a mixture of both live and Zoom talks to widen our speaker base. The Zoom meetings have also given everyone the chance to chat with society members based in England and further afield.

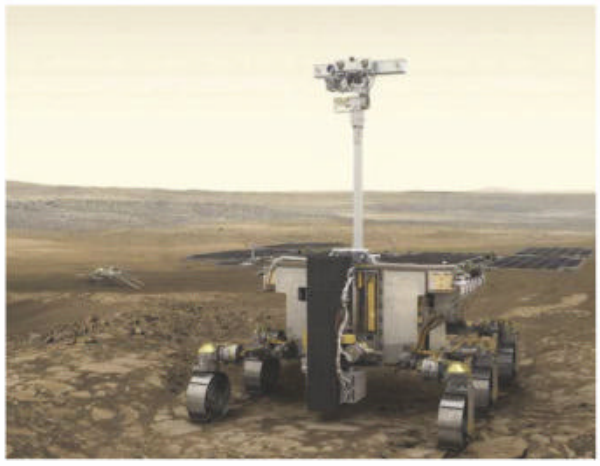
▲ **Members of Clydesdale Astronomical Society hold regular meetings via Zoom**

In May, Professor Axel Hagermann gave this year's John Braithwaite Memorial Lecture from Sweden. John Braithwaite was our Honorary President from 2007 until he passed away in 2012. He was the last maker of astronomical telescopes in Scotland, but there was a great deal more to him – he was the kindest soul on the planet! The committee and members felt it was a fitting tribute to hold a prestigious lecture each year in his memory.
Alice-Amanda Kay, Chair, Clydesdale Astronomical Society
▸ www.clydesdaleastro.org.uk

COVID-19
Online and socially distanced events taking place this month

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON



TALKS

Online The ExoMars 2022 mission

12 July, 7pm

West Didsbury Astronomical Society welcomes everyone to this Zoom talk by Rickbir Bahia of the European Space Agency, about ESA's Mars mission and the Rosalind Franklin rover due to launch next year. Book at **http://wdas2.com**

Online Current and future Mars missions

University of Bath, 21 July, 6pm

Professor Andrew Coates from UCL's Mullard Space Science Laboratory shares his excitement about the golden age of Mars exploration we're living through and his hopes for future missions. (It will take place live at the university's campus if restrictions ease.) Book at **bit.ly/3ozxJkP**

Online The Appley Bridge Meteorite

30 July, 7.30pm

Ashford Astronomical Society hosts author Russell Parry's Zoom talk on the events surrounding the Appley Bridge meteorite strike of 1914 – including confusion with enemy Zeppelins and confiscation by the police. To join, email **chairman@ashfordastro.org.uk**

Live Scilly Solar Observing

St Martins, Isles of Scilly, Fridays, 2pm

Join the friendly team at the Community Observatory St Martins on Scilly for one of their regular Friday solar-observing sessions. £5 for adults, £3 for under-16s. To book, email **cosmosscilly@gmail.com**

ESA/ATG MEDIALAB, NATIONAL SPACE CENTRE X 4

PICK OF THE MONTH

▲ Fun for all the family: the National Space Centre is celebrating its 20th birthday this summer

Live and Online National Space Centre

Space-flavoured summer activities for kids, 10 July–5 September

If you're going to be in charge of little people this summer, you can find lots of hands-on, fun, space stuff to do courtesy of the National Space Centre in Leicester. The centre, which is celebrating its 20th birthday, is running Earth from Space sessions, looking at the role of satellites in Earth observation, with a trail to spot the replicas around the centre, including Sputnik, Prospero and Orion-1. With group sizes kept small, booking is essential.

For home activities, see the centre's 'Space Crafts' sections on its website: you can create an exoplanet, make a DIY spectroscope, try out astronaut training and more. **spacecentre.co.uk/whats-on**

Live Summer stargazing

Nr Hexham, Northumberland, during July

Hunt for noctilucent clouds, constellations, summer double stars and planets at a Battlesteads Hotel stargazing evening. Equipment supplied. Tickets £22.50, £19.50 concessions. **bit.ly/3ox2AhT**

RADIO

New Thinking: From Life on Mars to Space Junk

Seb Falk and guest science historian Dr Joshua Nall look at our fascination with Mars and how perceptions have changed, then Timothy Peacock looks at Skylab, the first US space station. **bbc.in/3hGgJlk**

DOCUMENTARY

8 Days: To the Moon and Back

"This trip of ours to the Moon may have looked to you simple... but beneath the surface are thousands and thousands of others," said Apollo 11's Michael Collins. Grippingly recreating the eight days, three hours, 18 minutes, 35 seconds of that 'trip', 52 years ago this month, this film features previously classified cockpit audio and archive footage. **bbc.in/3v6jCWG**

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling 020 7566 1505

or email legacy@stroke.org.uk

or visit stroke.org.uk/legacy

Rebuilding lives after stroke

Stroke Association

FIELD OF VIEW

When NASA's legends came for dinner

Michael G Neece tells the story of Carol Jenzano, who grew up with astronauts

▲ Clockwise from top left: 1: Pete Conrad (Apollo 12), Elliot See (astronaut), Myrtle Jenzano, Neil Armstrong (first moonwalker); 2: Pete Conrad with Carol Jenzano; 3: Tony Jenzano, Mike Collins (Apollo 11), Carol Jenzano, John Young (Apollo 10 & Apollo 16); 4: Myrtle Jenzano (facing away), Tony Jenzano Jr, Carol Jenzano, neighbour, Pete Conrad

One evening in June of 1965 in the small town of Chapel Hill, North Carolina, 18-year-old Carol Jenzano answered her front door to find astronaut Pete Conrad grinning at her. She led him to the kitchen where she was cooking with her parents, Tony and Myrtle. "I called everybody I knew and they all told me to go to hell, so I decided to come here early," said Conrad as his grin widened. "What's for dinner?"

Carol Jenzano's father, Tony Jenzano, was the director of Morehead Planetarium, where he oversaw NASA's celestial navigation training programme. Astronauts trained at Morehead during the day, then spent time at the Jenzano home most evenings.

Carol Jenzano recalls: "They were very relaxed and charming, and they had fun at the house. I was always excited when Pete Conrad came to town because he was the most personable of all of the astronauts."

During Conrad's visit, Jenzano knew that more astronauts would arrive soon, including Neil Armstrong, her innocent crush. When the phone rang, her mother took the call in the kitchen and she tiptoed silently behind. The mischievous Conrad followed.

When Jenzano asked, "Mom, was that Neil?" her mother replied, "Yes, he'll be here soon." Conrad laughed and said, "Oh! So that's how it is!"

When Armstrong arrived, Conrad said: "Hey, Neil! Good to see you. Why don't you come sit over here next to Carol?" Jenzano enjoyed the good-natured teasing.

Jenzano recalls her father being quite the host, but says, "Mom was the life of the party." She remembers Armstrong's comment: "We just flew in, put our things at the motel, and then homed in on the raucous laughter." Jenzano confides: "He meant my mom's."

Astronauts enjoyed quiet access to Chapel Hill because of Tony Jenzano's policy: planetarium staff and family were never to reveal when astronauts were in town. The press would be notified only after. Carol Jenzano recalls: "My father said, 'You can't tell anybody'... then pictures would come out in the paper and my friends would complain, 'You didn't tell me!'"

What are Jenzano's thoughts about growing up with these space uncles? "They were unique and intelligent, clever and adventurous, and a little bit dangerous. It kind of oozed off of them, you know what I mean?"

We can only imagine, Carol. Thanks for helping us try.

Michael G Neece is the author of *Tony Jenzano, Astronaut Trainer*, published by The University of North Carolina Press

CAROL JENZANO COLLECTION x4, MICHAEL G NEECE

BBC

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BBC Sky at Night MAGAZINE

ILLUSTRATION

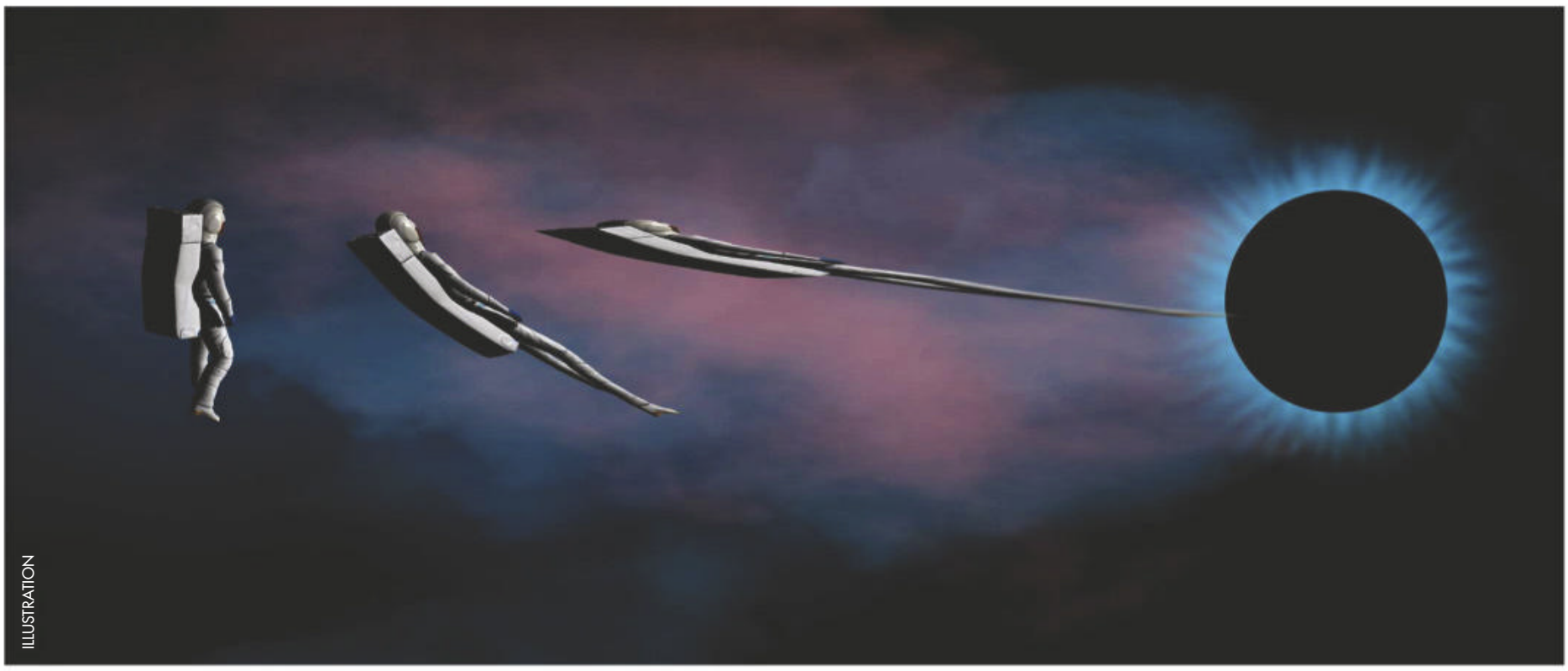
NAKED BLACK HOLES

Physicists have long held that black holes must be clothed in an event horizon, but **Colin Stuart** considers whether the concept is a convenient cover-up

Black holes are many things: cosmic trap doors, gravitational behemoths and shredders of stars. But black holes are also bashful – they hate to be naked in public. At least that's what we used to think. A run of recent research is calling this decades-old notion into question, and with it could come answers to other mysteries that have been stubbornly hard to solve.

A black hole is a region of the Universe where gravity is so extreme that it is impossible to escape from. The closer you get, the faster you need to travel in order to successfully run in the opposite direction. But get too close – past a boundary known as the 'event horizon' – and you'll need to travel faster than the speed of light to flee. As far as we know this is impossible and so your fate is sealed: the mega gravity of the black hole will tear you limb-from-limb in a process known as 'spaghettification ▸

BURADAKI/ISTOCK/GETTY IMAGES



ILLUSTRATION

▲ **Get too close to a black hole and its intense gravity would stretch you out in a process known as 'spaghettification'**

► According to our best theory of gravity, Einstein's theory of general relativity, your spaghettified body would eventually end up at a 'singularity' – an infinitely small and dense point at the 'bottom' of the black hole. Indeed, the very notions of space and time cease to exist at a singularity and any traces of you will be erased from the Universe.

Cosmic conundrum

It's far from a desirable outcome, either for you or for the theoretical physicists who study black holes; if space and time disappear in a puff of smoke then so does our ability to explain what's going on.

"It's where the laws of general relativity break down," says Elena Giorgi, a postdoctoral research associate at Princeton University. You can see for yourself the issues caused by an object with a significant mass but zero size. Just try dividing any number you like by zero on a calculator. As Giorgi says: "It tells you that something isn't right."

In the 1960s, Roger Penrose, the Nobel-prize-winning physicist and long-time collaborator with Stephen Hawking, proposed a solution to get around this embarrassing situation. He said that a singularity must always be dressed with an event horizon; in other words, no 'naked' singularities are allowed. It saves both the black hole's blushes and our own, conveniently hiding a place we can't explain behind a layer of clothing we can never see past, as no light can escape from inside the event horizon to show us what's happening in there. That way there's no part of the observable Universe that general relativity

ILLUSTRATION

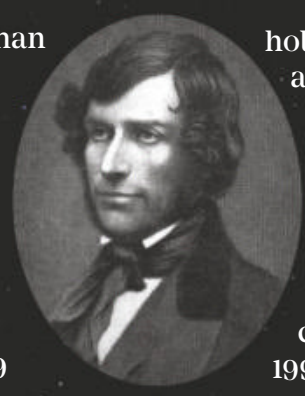
▼ **In the conventional black hole model an event horizon forms around the black hole itself**

TIM BROWN/SCIENCE PHOTO LIBRARY, NAEBLYS/ISTOCK/GETTY IMAGES, SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO, SPANTELDOTRU/ISTOCK/GETTY IMAGES

A brief history of black holes

The difficulties of seeing something which steals all light has kept black holes hidden for centuries

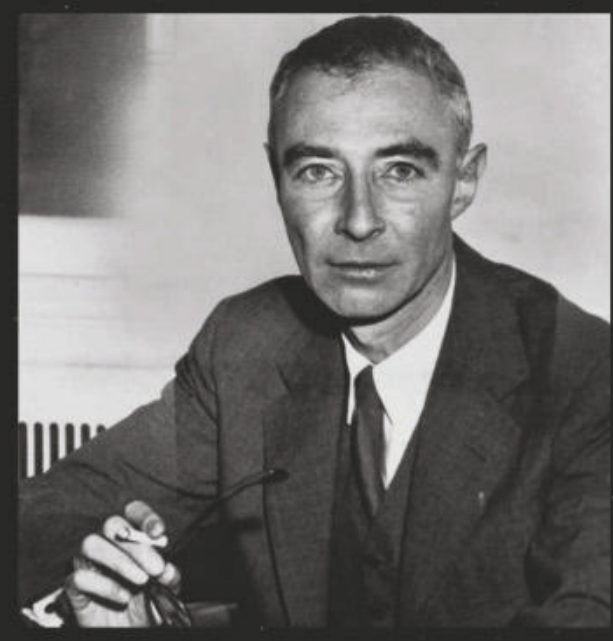
The idea of a black hole is older than many people realise. As far back as the 18th century, Englishman John Michell (pictured, right) wondered whether you could add enough mass to the Sun so that light wouldn't be able to leave its gravitational clutches.



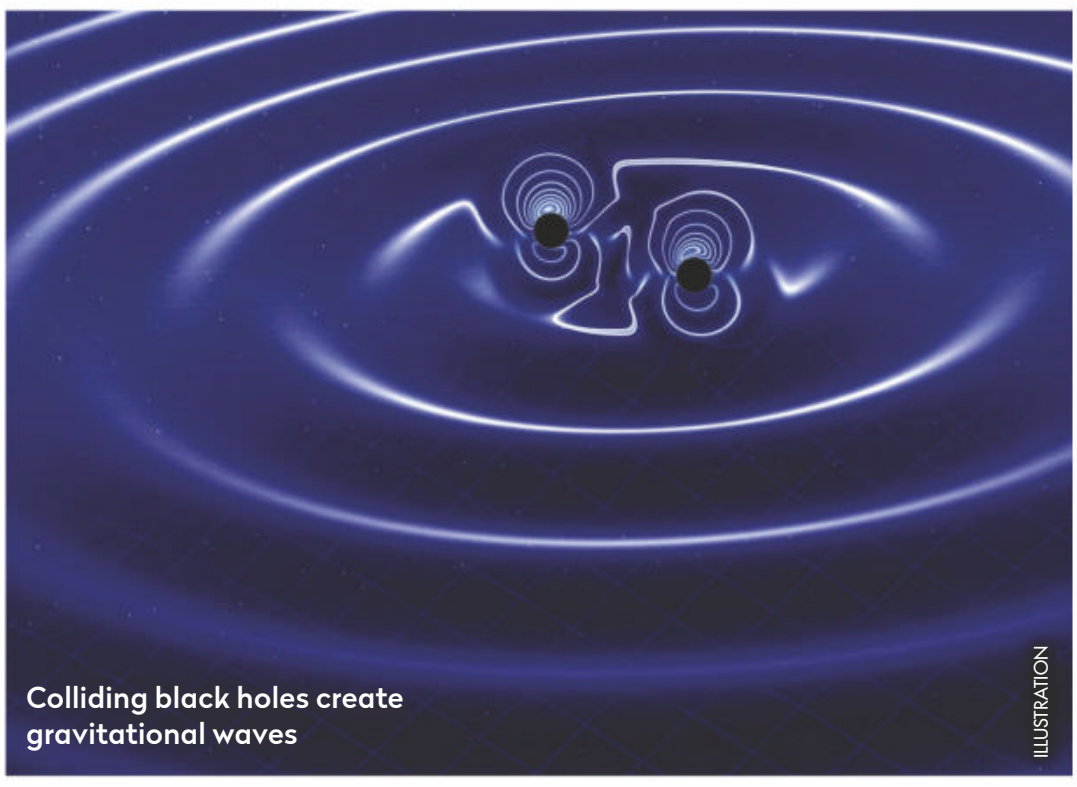
The first modern incarnation of a black hole appeared in a 1939 paper by Robert Oppenheimer, the famed leader of the Manhattan Project. Called *On Continued Gravitational Contraction*, Oppenheimer speculated that if the core of a collapsing star has sufficient mass it would become what we now call a black hole. The phrase 'black hole' itself wouldn't appear for another three decades: it was coined by John Wheeler in 1967.

Circumstantial evidence for their existence arrived in the 1970s when astronomers saw intense X-ray radiation coming from the region around a compact object. Then, in the 1990s, we saw stars being flung around the centre of our galaxy in a way that suggests they're orbiting a four million solar mass monster – only a supermassive black hole fitted the bill.

Finally, concrete evidence came first in 2015 when the Laser Interferometer Gravitational Wave Observatory (LIGO) detected gravitational waves from black hole collisions. Then, in 2019, a network of radio telescopes, known as the Event Horizon Telescope, revealed the first ever image of a black hole to be captured.



▲ **Oppenheimer first proposed the concept of a black hole as we know them today**



Colliding black holes create gravitational waves

ILLUSTRATION

The fact that general relativity appears to break down in the centre of a black hole suggests that there may be a deeper theory of gravity we've yet to uncover

can't describe. This get-out-of-jail-free card is called the Weak Cosmic Censorship Conjecture (WCCC).

If you think the WCCC sounds a little too convenient – because, while an event horizon is understood mathematically, we aren't 100 per cent sure how it manifests physically – you could be right. "There's no proof of it," says Tomas Andrade, a postdoctorate researcher at the University of Barcelona.

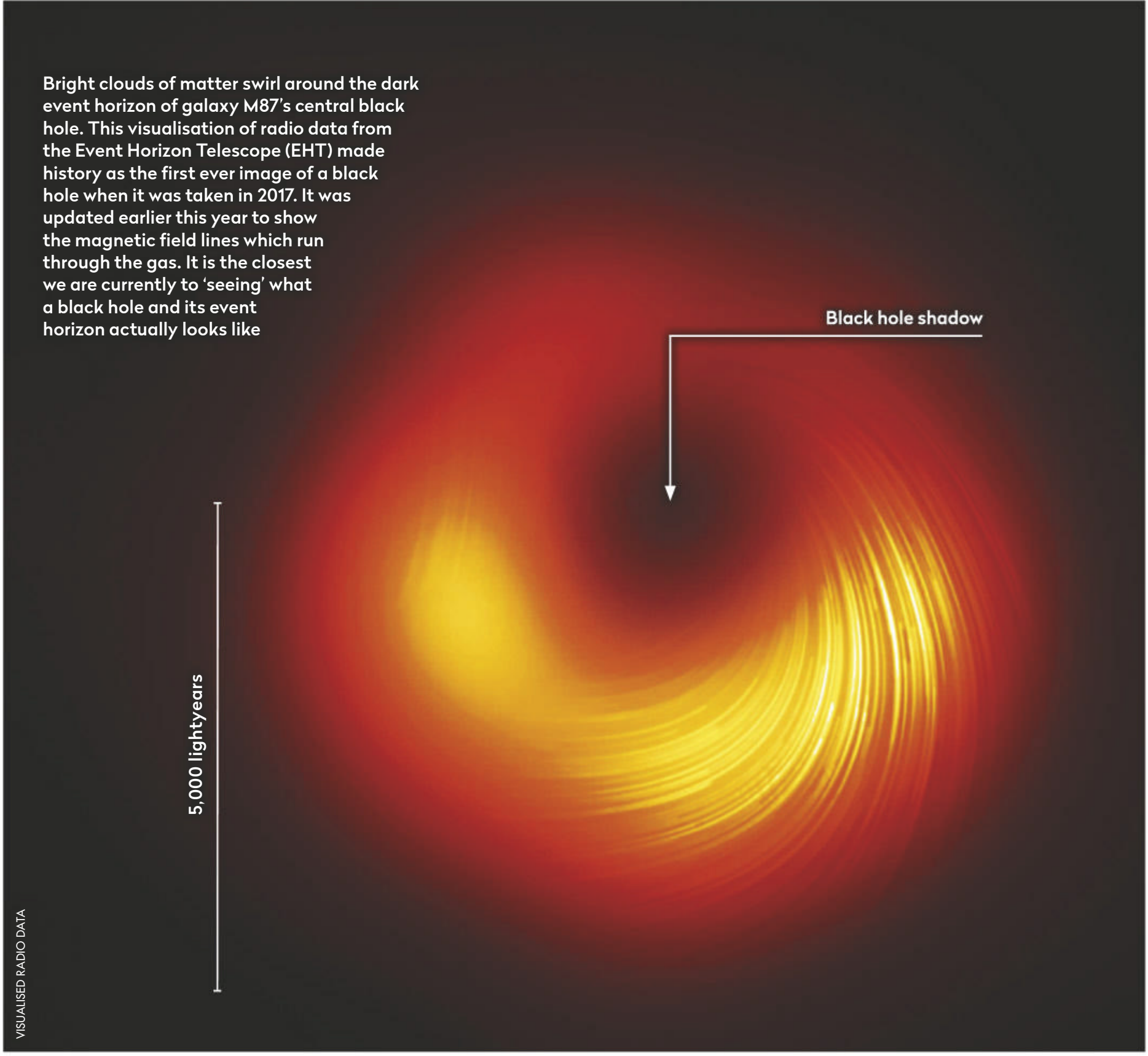
The fact that general relativity appears to break down in the centre of a black hole suggests that there may be a deeper, more comprehensive theory of gravity out there we've yet to uncover, just as general relativity is a more accurate picture of gravity than Isaac Newton's original work on the force. Physicists exploring some of these alternative theories have found that black holes can actually be horizonless after all.

Breaking the rules

Many physicists believe that we'll arrive at a more comprehensive theory of gravity if we can combine general relativity with quantum physics – the weird and wacky rules that govern atoms and the subatomic world. To get these two landmark theories to play nicely together, physicists often have to assume that the Universe contains more dimensions than the four we experience in our day-to-day lives (three of space and one of time). Andrade has recently discovered that it's possible to rip an event horizon right off in a universe with a total of six or seven dimensions of space. All you need is for two black holes to collide.

Thankfully, we already know that black hole collisions are commonplace – they created most of the gravitational waves we've detected in recent years with experiments such as LIGO in the US. The two black holes merge into one after the collision, but Andrade found the force of the impact elongates the event horizon of the new black hole. "It thins out and becomes unstable," he says. The event horizon then fragments in a similar way to water separating into droplets as it emerges from a leaky tap. Before long the naked singularity underneath is exposed.

There were some pretty tight restrictions required to get this to work, though. The speed with which the ▸



Bright clouds of matter swirl around the dark event horizon of galaxy M87's central black hole. This visualisation of radio data from the Event Horizon Telescope (EHT) made history as the first ever image of a black hole when it was taken in 2017. It was updated earlier this year to show the magnetic field lines which run through the gas. It is the closest we are currently to 'seeing' what a black hole and its event horizon actually looks like

VISUALISED RADIO DATA EHT COLLABORATION, ESO

▸ black holes collided had to be not too slow or fast. In addition, the black holes themselves had to be spinning fairly rapidly to begin with. Plus, of course, we don't even know if the Universe really has extra dimensions. "The validity of these modifications isn't clear," says Giorgi. Even if it does, it could prove hard to observe such collisions as gravitational waves – the only way we can currently detect such mergers – become suppressed in higher dimensions.

Beyond the horizon

However, black hole collisions aren't the only way to whip away an event horizon. One of Stephen Hawking's most famous ideas is known as Hawking radiation. By leaking particles back into space, a black hole can very slowly evaporate away.

"The Hawking evaporation process may turn an electrically charged black hole into a horizonless naked singularity," says Professor Shahar Hod from Israel's Ruppin Academic Center. Except, Hod's black hole is about as charged as it is possible to get. But this could be a stretch, as any electric charge would be quickly absorbed by the clouds of material which gather around the event horizon. That said, he argues that a highly charged black hole is equivalent to one that's rotating very rapidly: "Such fast-rotating black holes are expected to exist in the centres of galaxies."

It may even be possible for a black hole to form without an event horizon at all – naked at birth, just like us. A team led by Dr Yaser Tavakoli, from the University of Guilan in Iran, looked at the collapse of dust clouds in a theoretical five-dimensional universe. They found that there was a mass threshold for the cloud, below which it would shrink to form what Tavakoli calls a "sudden singularity". In other words, one that is freely visible to an external observer.

So it seems that there are a number of ways to achieve a naked singularity, particularly in theories of gravity that seek to go beyond general relativity. If we're to get an insight into which, if any, of these ideas is on the right track, finding a naked singularity would surely help.

It may even be possible for a black hole to form without an event horizon at all – naked at birth, just like us

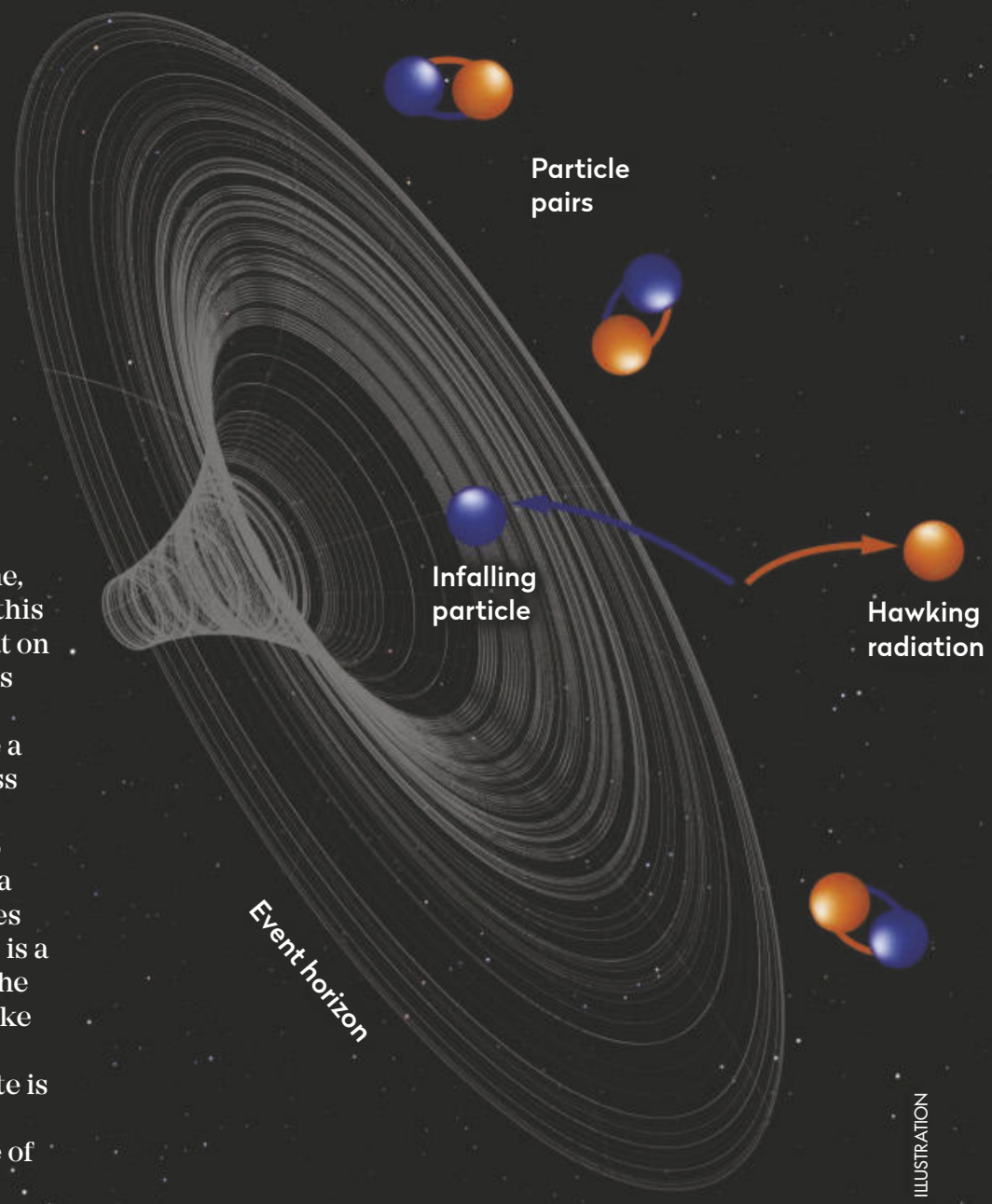
According to Wei-Hsiang Shao, from the National Taiwan University, that could be tricky: a naked black hole does a pretty good job of masquerading as one cloaked with an event horizon. He looked specifically at the shadows the black holes cast – dark zones

Hawking radiation

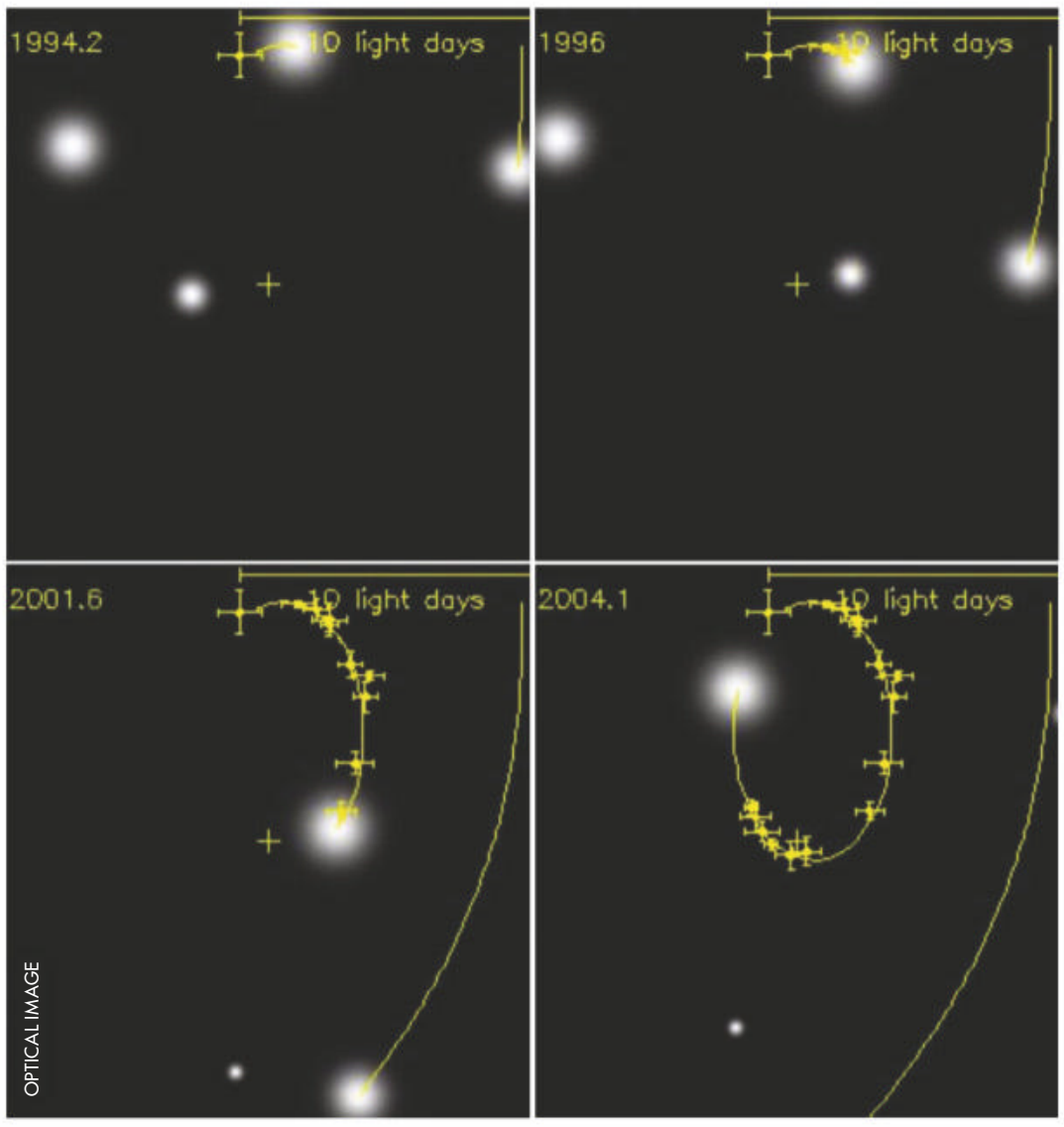
Particles appearing on the edge of a black hole could wear it down over time

Physicists know that on the smallest scales of the Universe pairs of particles pop into existence, suddenly appearing out of the vacuum only to rapidly recombine and disappear again. They are called 'virtual particles' and Stephen Hawking wondered what would happen if this process unfolded right on the event horizon of a black hole. If one particle crosses the event horizon then it is forever separated from its companion and can never recombine with it. The particles that are left outside the event horizon are called 'Hawking radiation'.

However, the particles had to 'borrow' energy from empty space to appear in the first place. Normally this debt is repaid when they recombine, but as that can't happen in this case they effectively default on the loan. The repayment has to come from somewhere: the black hole. So over time a black hole slowly loses mass due to the constant need to cover these energy debts to empty space. It means that a black hole slowly evaporates over time. Although 'slowly' is a bit of an understatement. The number of years it would take a black hole with the same mass as the Sun to evaporate is one followed by 64 zeros – many times the current age of the Universe.



ILLUSTRATION



OPTICAL IMAGE

▲ A sequence of images of a star orbiting the supermassive black hole at the centre of the Milky Way

around them caused by the extreme local gravity. These shadows were made famous by the first ever photograph of a black hole taken by the Event Horizon Telescope back in 2019 and updated again earlier this year. The naked singularity's shadow looked eerily familiar. "Features of the shadow closely resemble those of [an ordinary] black hole," he says in the paper detailing his research.

An intriguing alternative

Fortunately, Dr Dipanjan Dey, from Charusat University in India, thinks there's another way a naked black hole could reveal itself: by the way it affects stars orbiting around it. He discovered that a black hole without an event horizon would cause the stars' orbits to precess differently. Precession is a common phenomenon in astronomy where the closest point an object gets to the thing it is orbiting shuffles round over successive orbits, creating an orbit that looks something like a spirograph might draw. Dey has used this fact to predict the future paths of the stars orbiting around Sagittarius A*, the supermassive black hole in the heart of our Galaxy, the Milky Way.

Stars take a decade or more to complete one orbit around the black hole, and we only started looking in the mid-1990s, so we haven't seen many stars complete successive orbits yet. If our observations match Dey's calculations in the years ahead, it could be the first direct evidence that a black hole can violate Penrose's Weak Cosmic Censorship Conjecture. And with it the door could be opened into alternative theories of gravity that may one day knock general relativity off its perch.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at colinstuart.net/ebook

A twilight NIGHT'S TOUR

For some, short summer nights mean less observing, but there is a wealth of celestial beauty to be found at the Blue Hour, writes **Scott Levine**

Who doesn't love summer? School's out and it's the time of year for camping trips and beach holidays! Plus, the long days mean there's time for another ice cream as we watch the day melt into a sunset. Extra sprinkles, please.

Late sunsets mean night falls later, too. But, while the kids aren't in school, us adults still have to get up for work.

In the UK, the Sun doesn't set until after 21:00 BST (20:00 UT), and the last drops of sunlight don't leave the sky until midnight. So there isn't much true night when we're this close to June's summer solstice, but there's plenty of sky-watching we can do, especially if we start earlier, during evening's twilight.

So much can be seen as the Sun begins to set and the world gets a little darker. The twilight sky is largely too bright for deep-sky objects, so it's best to focus on what we can see with the unaided eye. If you do use binoculars or a scope to get a better glimpse at evening objects, remember: never look directly at the Sun, especially through magnification, unless you have special filters for solar viewing. You might also find it helpful to block the Sun with a large object, like the side of a building.

Now, let's see what twilight has to offer...

BIN KONTAN/ISTOCK/GETTY IMAGES, MENNO VAN DER HAVEN/ALAMY STOCK PHOTO

As dusk falls

Scott Levine is a naked-eye observer and an astronomy writer based in New York's Hudson Valley

While afternoon slowly turns into evening, we start the first stage of twilight. Civil twilight begins in London in the evening at 21:20 BST (20:20 UT) at the start of the month, and 20:49 BST (19:49 UT) at the end. You can read more about the stages of twilight in the box on page 38.

The effects aren't only in the sky. This might sound strange, but now is a great time to look away from the sky. With the Sun nearing the horizon, and the low atmosphere scattering more light, the pinks, oranges and purples of sunset reach out across the landscape. All around us the shadows of trees and posts lengthen, and the colours of cars and houses take on a soft orange glow.

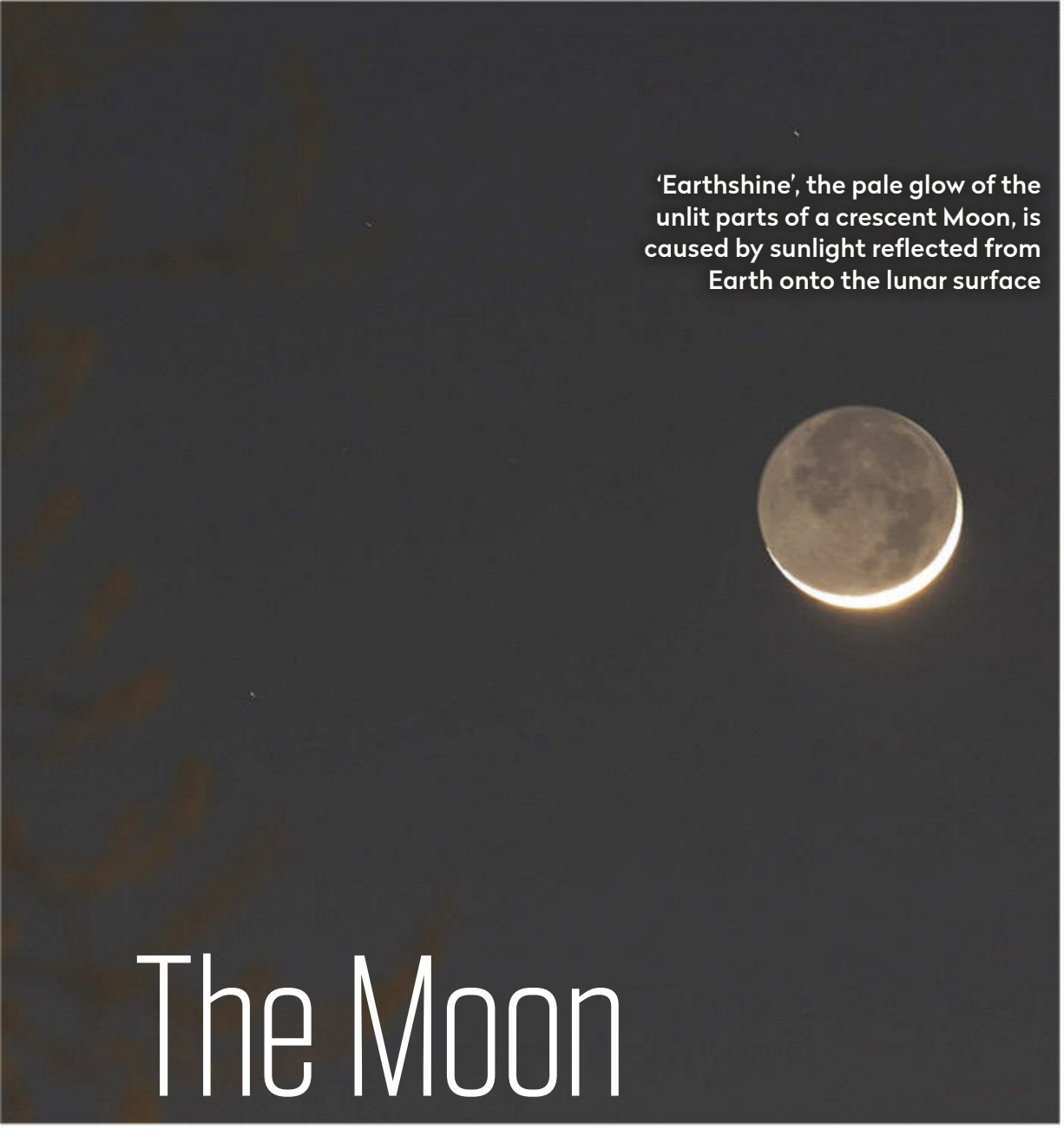
Don't forget to listen as well. Are there new bird songs? Can you hear any foxes or other animals scurrying around? As darkness settles, the bees and butterflies head home, while moths and bats take to the sky.

When the Sun falls to about six degrees above and then drops below the horizon, the shadows dissolve away. We're in the Golden Hour, so-called because of the soft, golden colour the remaining sunlight gives to everything we can see. There are no shadows left and the colours around us make it a good time for photography.

After this comes the Blue Hour, when the last of the remaining sunlight scatters and casts a blue glow into the dusk. We're using the word 'hour' loosely here. It refers to the part of the day, not to an actual amount of time.

This is when we might be able to see Earth's shadow – the same shadow that brings us lunar eclipses – cast onto the atmosphere as a broad and dark band just above the horizon opposite the Sun. Above it is the Belt of Venus, which is caused by scattered sunlight a bit higher from the ground, and this tends to be closer to pink. ▸

▼ The rosy-hued band, known as the Belt of Venus, lies above Earth's dark shadow at dusk



'Earthshine', the pale glow of the unlit parts of a crescent Moon, is caused by sunlight reflected from Earth onto the lunar surface

The Moon

Turn a telescope on the Moon and you'll see shadows dancing across the terminator

Depending on where it is in its orbit – what phase it's in – the first thing we'll see through the twilight is the Moon. This month, it's new on 10 July. In the days that follow, look for thin, sleepy crescents lagging behind the Sun. These early phases are a great time to look for earthshine: sunlight that bounces off Earth onto the Moon. It gives the Moon's night-time side a gorgeous dim and dusty glow. Who knows, maybe some of the photons we're seeing bounced off us!

As the week goes on, the Moon sets later and later, moving farther to the east (to our left) by about 13° each night.

On 17 July it reaches first quarter and doesn't set until before midnight. For a couple of days on either side we can see it in broad daylight without too much trouble, in that strange part of the day that was evening a few months ago but is still afternoon now.

This is a great time to point a pair of binoculars or a small telescope at our nearest neighbour. There's an understated, stark beauty to seeing it in the late afternoon, and the sight of long shadows on the Moon's craters in the calm glow of early evening twilight has a soothing quality, even after the toughest of days.

Twilight's changing face

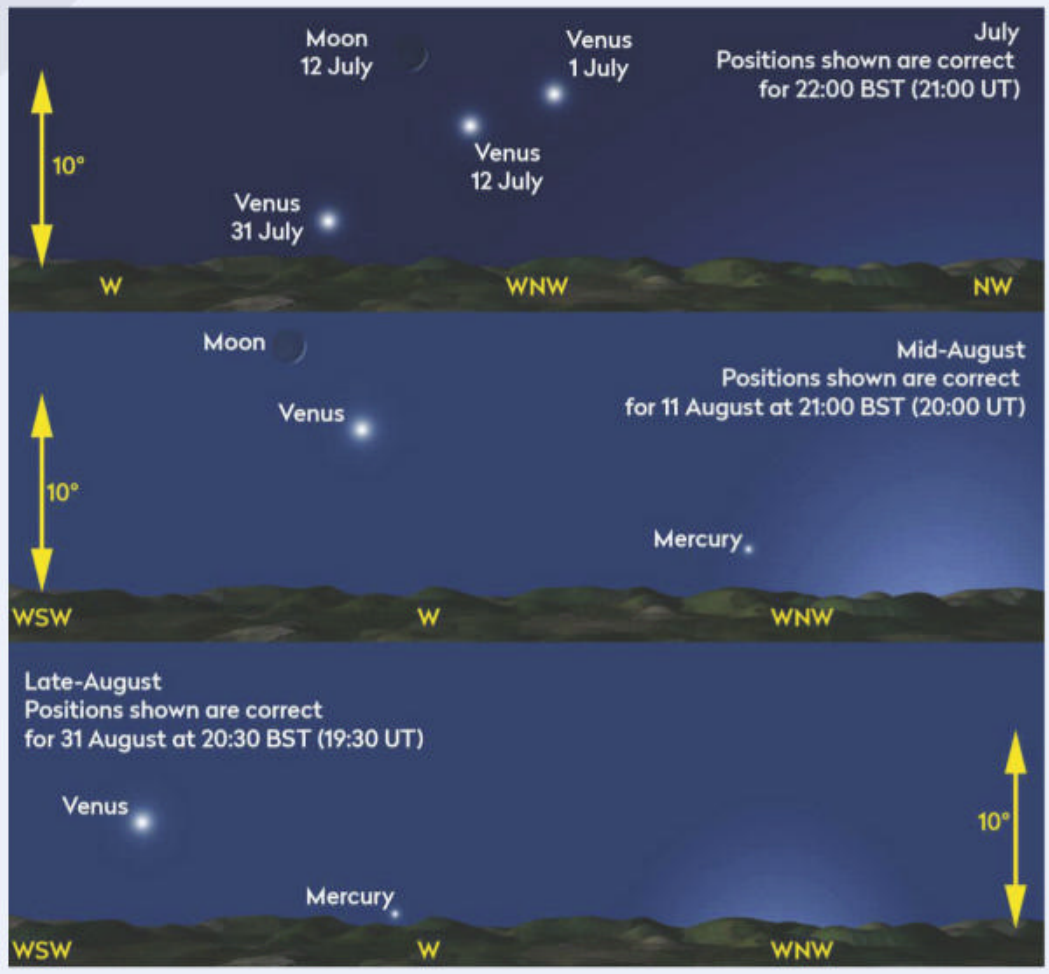
As afternoon ends and another July night settles in, check these celestial sights off your twilight observing list

Late afternoon: It's easiest to find the Moon in the southwest a couple of days before and after first quarter (approx. 15–19 July).

21:30 BST (20:30 UT): Near sunset, you might spot Venus in the west. Vega (Alpha (α) Lyrae) in the east, Arcturus (Alpha (α) Boötis) in the south, Antares (Alpha (α) Scorpii) low in the south, and Capella (Alpha (α) Aurigae) in the northwest are the first stars to be visible.

22:00 BST (21:00 UT): You'll see second, third and fourth magnitude stars. It's easier to see the stars of the Spring and Summer Triangles high in the east and south, and the Plough too. The constellation of Scorpius, the Scorpion is also an easy spot.

23:00 BST (22:00 UT): There is still some sunlight left, but more stars fill the sky. The Teapot of Sagittarius, the Archer chases behind Scorpius.



PETE LAWRENCE X 2, CHRISTIAN FRIEBER/CCDGUIDE.COM, MENNO VAN DER HAVEN/ALAMY STOCK PHOTO, GALAXY PICTURE LIBRARY/ALAMY STOCK PHOTO

Naked-eye planets

The next things we're likely to see in the deepening dusk are our Solar System's bright planets. Though we don't typically think of the planets as twinkling in the way stars do, we might notice it a bit in the early evening as their light struggles with the low-lying atmosphere.

It's always fun to try to find planets in this part of the evening as they make their way through twilight. The sky is still too bright for most stars, which makes it easier to be sure we're looking at a planet. Once you find them, keep an eye on them until they set, and then follow them as they wander across the sky from evening to evening.

Venus and Jupiter are the two brightest things in the sky after the Sun and the Moon, so depending on where they (and the Moon) are in the sky, they might be the first things we see.

Venus is stunning in a deep, dark sky, but the twilight version has a simple, understated beauty. It seems to arrive without any complications or celebrations. Although its position is on the low side this month, you'll find it in the western twilight and it sets just after the Sun, where it almost feels like spotting a friend waving through a crowd. Mars will be there this month, too, but it's small, and its reddish-orange colour blends in somewhat with the sky around it.

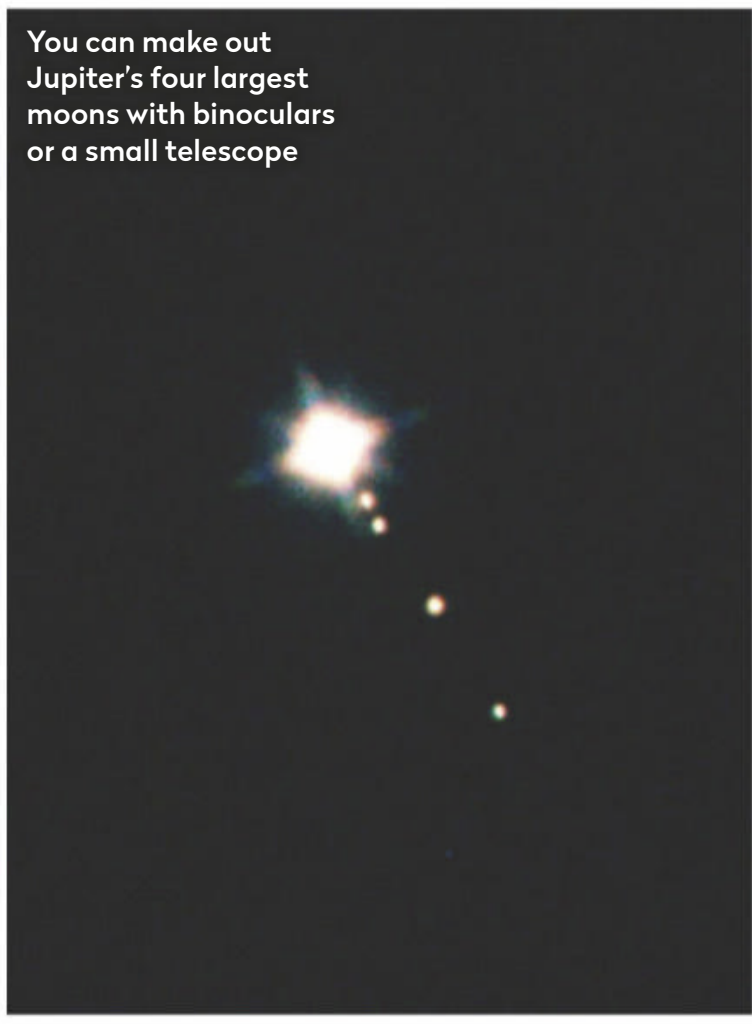
Venus is stunning in a deep, dark sky, but the twilight version has a simple, understated beauty

Through July, Venus rises a little towards the west, while Mars sinks towards the northwest each night. Step out on the evening of 13 July and the two planets will be less than half a degree apart just above the western horizon, with a young crescent Moon nearby. Binoculars will help separate the two planets in this stunning scene. Although Mars will vanish by early August, Venus stays visible but is low to the horizon.

Early twilight is a good time to try and find speedy Mercury. The innermost planet never gets more than 28° of arc from the Sun, so most of the time it's only visible in twilight. This month, we might be able to spot it in the morning twilight, just before sunrise.

Jupiter and Saturn don't rise until a bit deeper into the night this month. But, if you want to stay up a later, a regular pair of binoculars will reveal Jupiter's four giant Galilean moons. And, thanks to its rings, Saturn might look a little egg-shaped. ▸

A conjunction of Venus and the Moon, captured in April 2020



You can make out Jupiter's four largest moons with binoculars or a small telescope

The first stars

There's an incredible moment that happens every evening as we enter twilight's second stage – the first stars pop into the night sky (although you might be able to spot some earlier). This nautical twilight phase starts at 22:07 BST (21:07 UT) on 1 July and 21:30 BST (20:30 UT) at the month's end.

Most of us who know our way around the sky can identify one star from another by context – recognising the patterns of the other stars around them. However, at twilight, the only stars whose light penetrates the glow are generally the brightest. For experienced sky watchers, it can feel disorienting, like being a bit lost in a city you're visiting for the first time. But this means newcomers can use the lingering twilight to get to know constellations. Just find the brightest stars and then watch as darkness fills in the patterns around them.

It's a pleasure to watch the sky change in minutes to being filled with stars. There are eight first magnitude stars in July's sky. The first stars we are likely to see are Arcturus (Alpha (α) Boötis) in the south or Vega (Alpha (α) Lyrae) in the east. After Vega, it won't be long before we can make out others, including Altair (Alpha (α) Aquilae) and Deneb (Alpha (α) Cygni), the Summer Triangle's other two corners, in the east. Believe it or not, these stars will still be in our skies for months, until they vanish into January's western twilight. While this is going on, Spica (Alpha (α) Virginis) and Regulus (Alpha (α) Leonis) – the other Spring Triangle stars – join the fun with Arcturus. These two are a little hard to see. If the horizon to the north is clear, you might spot Capella (Alpha (α) Aurigae) just above it.

As we move through nautical twilight, we'll see many more stars, including Polaris, the North Star.

▲ The first 22 objects to appear in the night sky, mid-July:

1 Jupiter
2 Arcturus
3 Vega
4 Capella
5 Saturn
6 Altair
7 Antares
8 Spica
9 Deneb
10 Castor
11 Alioth
12 Dubhe
13 Mirfak
14 Kaus Australis
15 Alkaid
16 Menkalinan
17 Polaris (the North Star)
18 Algieba
19 Mizar
20 Nunki
21 Mirach
22 Alpheratz

The stages of twilight

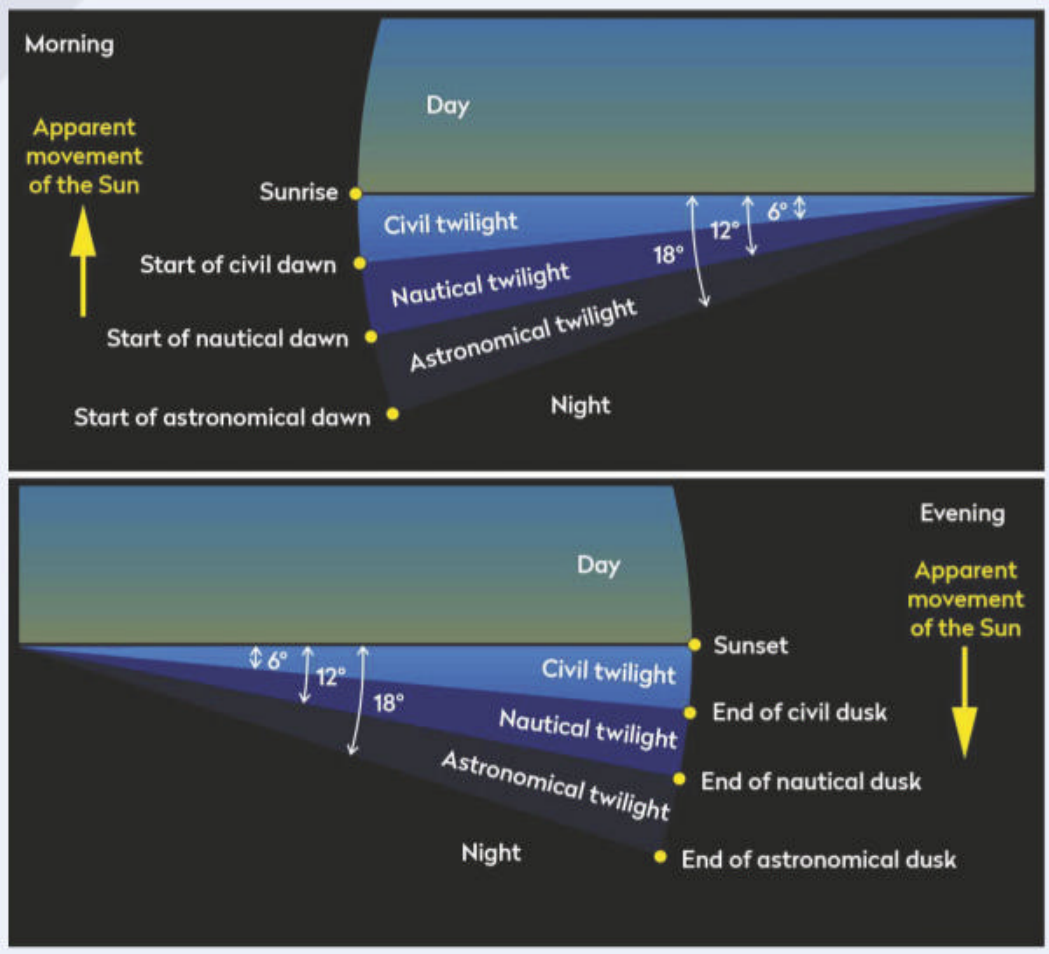
We generally group the gradual changes of twilight into three stages

Stage 1 During **civil twilight** the Sun has set, but there is still enough light left to see without streetlights. This stage lasts until the Sun's centre is 6° below the horizon.

Stage 2 When the Sun is between 6° and 12° below the horizon it is **nautical twilight**. Extra light is needed to help walk around, but enough celestial objects become visible to navigate by the stars.

Stage 3 The last stage of evening twilight is called **astronomical twilight**. It's when the Sun's centre is between 12° and 18° below the horizon. There is still some lingering sunlight, but it's dark enough for astronomy work to begin. After this, night begins.

This is their order in the evening. Before dawn, they're reversed: night, astronomical, nautical and then civil twilight.



PETE LAWRENCE X 4, MIKEMAREEN/ISTOCK/GETTY IMAGES

Noctilucent clouds form when water vapour accumulates and freezes around specks of meteor dust floating in the atmosphere

Deep-sky objects and noctilucent clouds

Keep an eye on the stars you've found so far and make your way into astronomical twilight – 23:19 BST (22:19 UT) in early July, and 22:24 BST (21:24 UT) at the end.

By now, you can see Antares (Alpha (α) Scorpii), the red supergiant in the constellation of Scorpius, the Scorpion, which is low towards the south and has been hidden away by lingering sunlight.

Next, look for some of the other stars near the Summer Triangle. Can you see the Northern Cross? How about The Teapot asterism of Sagittarius, the Archer? You'll find it chasing the Scorpion, low towards the southeast.

These stars are mostly of second, third and even fourth magnitude. The dimmer they are, the longer they'll take to make their way into the night. Scan the skies with binoculars or using a small telescope. Maybe you can spot the Double Cluster (NGC 869 and NGC 884) in the constellation of Perseus, the Hero, the Andromeda Galaxy, M31, or the Hercules Cluster, M13.

During astronomical twilight in the summer, you might also be able to see noctilucent clouds. These aren't true clouds, but ice crystals high in Earth's atmosphere that reflect sunlight and look like wispy, delicate clouds. The further north you are, the better luck you'll have seeing them. Just make sure you have a clear northern horizon and look while the sky is still just about lit by the now-set Sun. Point binoculars towards the noctilucent clouds and see what their delicate and wispy patterns look like magnified.

▲ A simulation of the Double Cluster as seen through 7x50 binoculars...

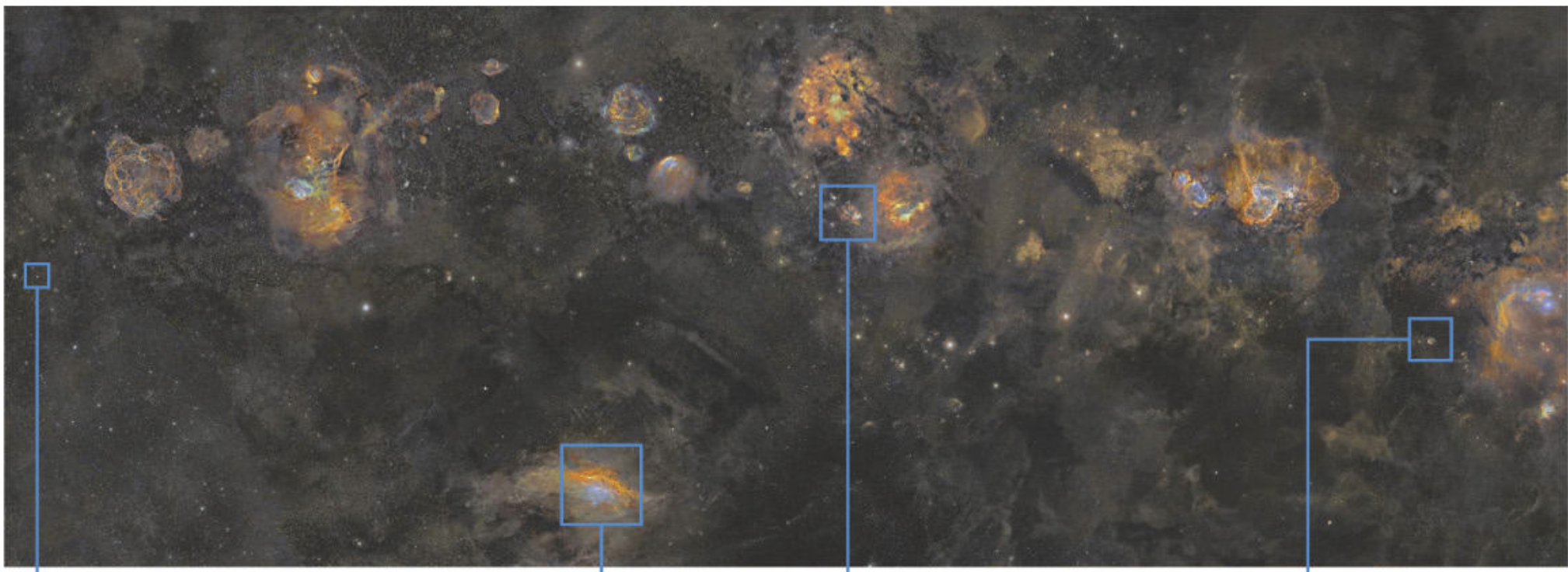
▲ ...and a simulation of the Andromeda Galaxy, M31, as also seen through 7x50s

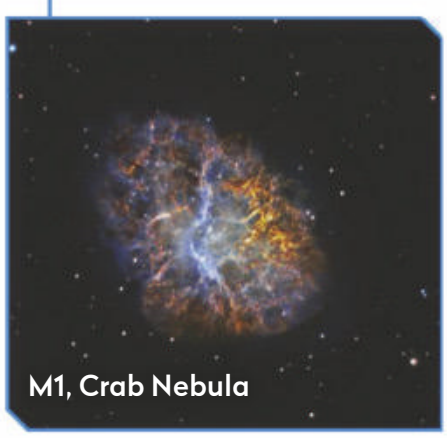
With a little bit of patience and luck there are some truly incredible things to look for before dark

After this, the sky keeps darkening until our part of the world has turned fully away from the Sun. It's night at last, and perhaps time to head back inside until tomorrow's twilight.

As wonderful as they are, summer nights can be short and difficult for those with a hankering for true darkness. But with a little bit of patience and luck, and some good timing, there are some truly incredible things to look for before dark.

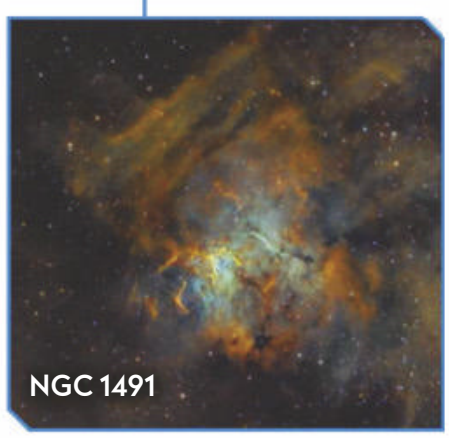
A mega Milky Way mosaic





M1, Crab Nebula

NGC 1499, California Nebula

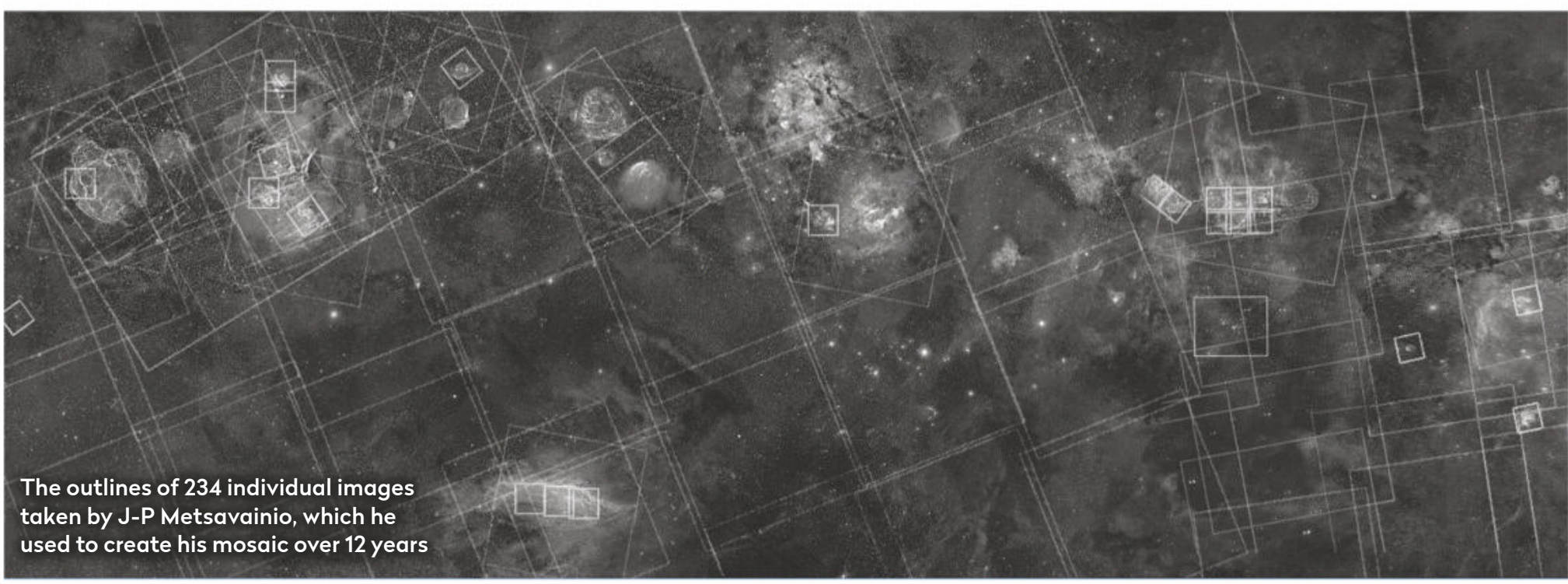


NGC 1491

SH2-188

My work is an endless curiosity: I love to see and show how wonderful our Universe really is. Our Galaxy may be one of many billions in the Universe, but it's our home. This makes it special not just to me, but all of us on Earth. It's important to know what's going on in our cosmic backyard, and before I created this mosaic there was no image like it that I knew of. I'm thrilled about all the details I managed to get from the emission nebulae in this mosaic, which also contains several supernova remnants seen for the first time in their full glory.

Astrophotography is one of the most difficult forms of nature photography. Exposure times are long, especially for narrowband imaging, and also when you need to capture dim objects. There are several individual frames in this mosaic that each contain 100–200 hours of exposures, and it took several years

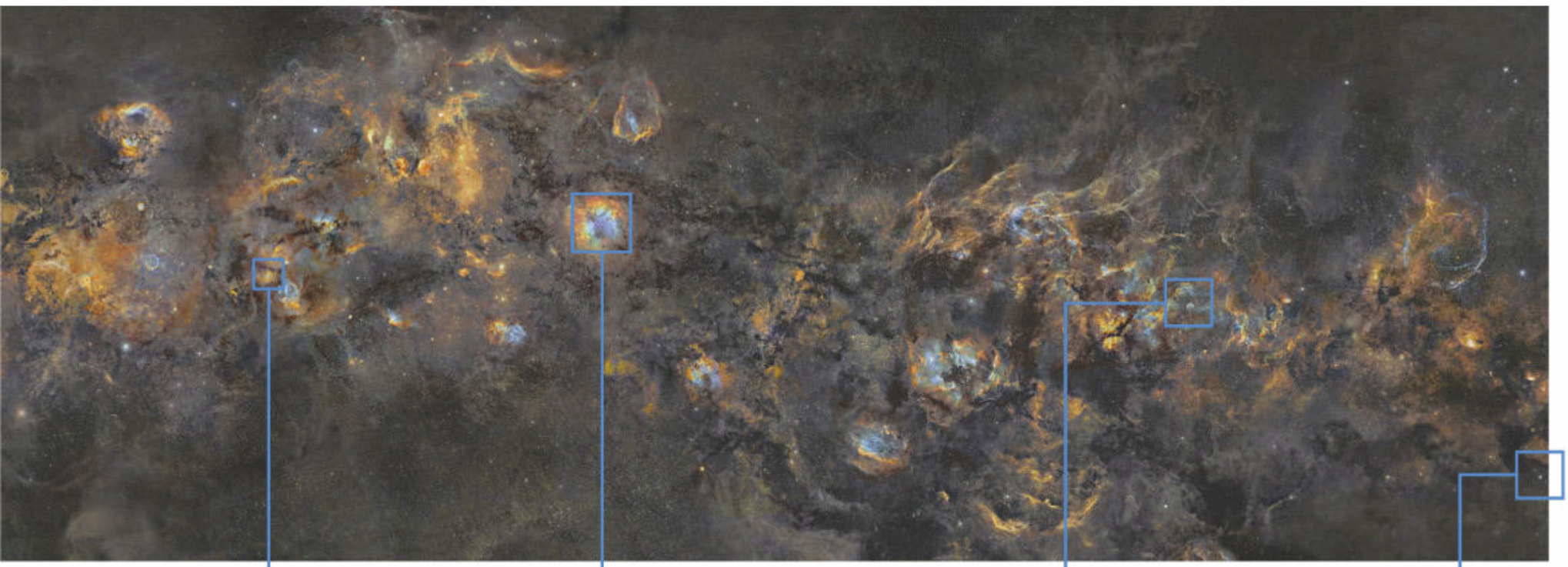


The outlines of 234 individual images taken by J-P Metsavainio, which he used to create his mosaic over 12 years

ALL PICTURES: J-P METSAVAINIO

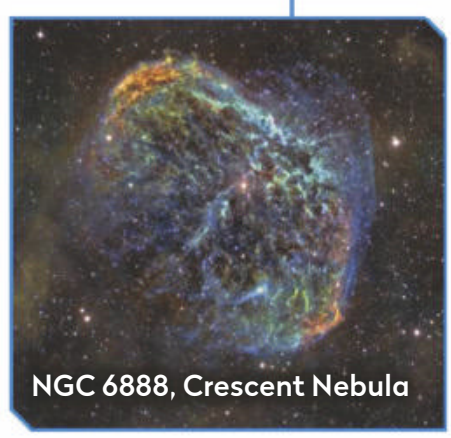
Astrophotographer **J-P Metsavainio** spent 12 years photographing the Milky Way and stitching together a mesmerising panorama of our home Galaxy

J-P Metsavainio is a Finnish visual artist and astrophotographer

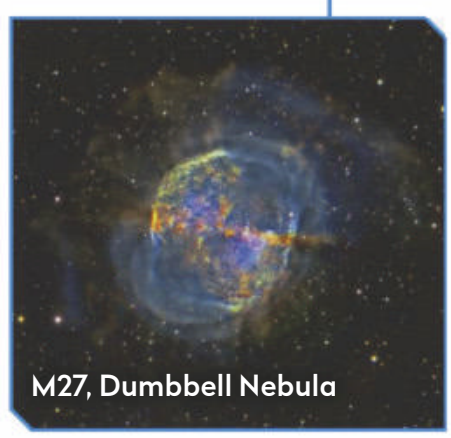


NGC 7635, Bubble Nebula

IC 1396, Elephant's Trunk Nebula



NGC 6888, Crescent Nebula

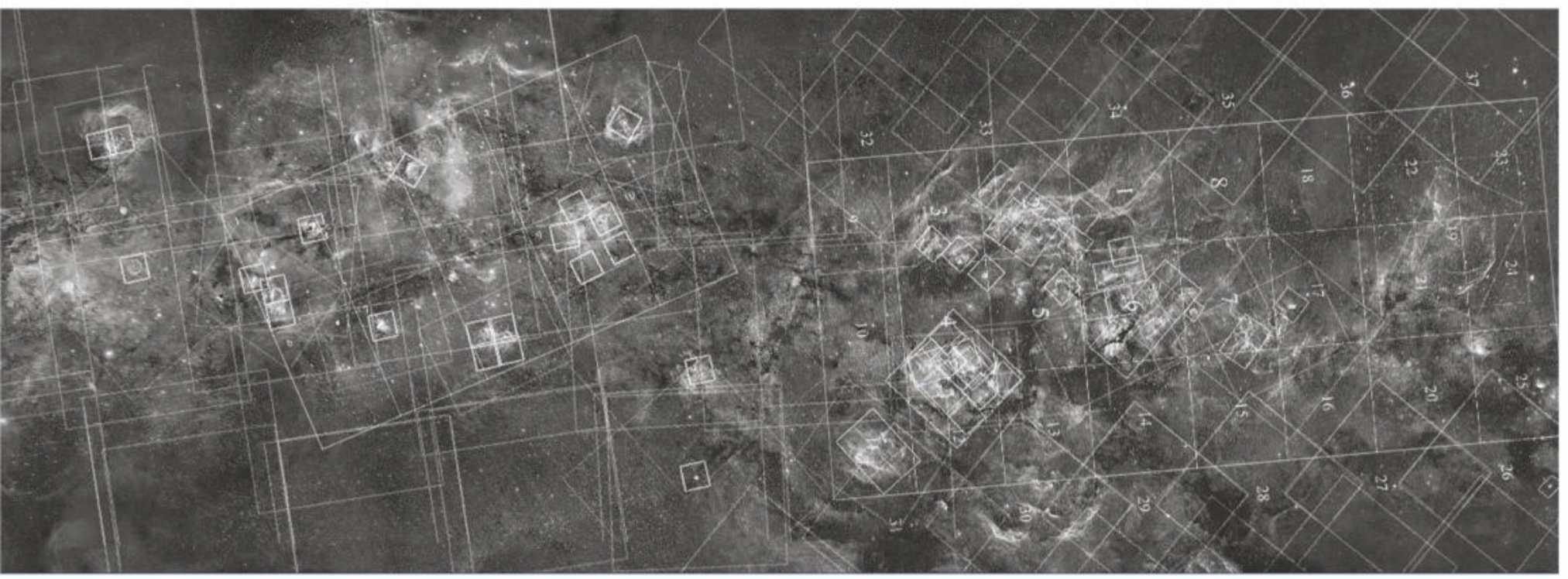


M27, Dumbbell Nebula

to collect enough light to show them well. I've gone through various cameras and optical configurations, but it's not so much about fancy gear; it's about experience and knowhow.

Every frame has to be shot three times and, since astrophotography cameras often have a grayscale sensor, each colour channel has to be shot separately. After image processing with calibration, stacking and non-linear stretching, the channels are combined into an RGB image, and the colour balance, white and black points, levels and curves are fine-tuned.

I planned this project over a decade ago, and over the years I shot targets within the Milky Way as individual captures, but I always kept my long-term goal in mind. I did have doubts, however, about why exactly I was doing this, and its detrimental effect on my social life and finances! But every time I saw a new image finalised, I would be as thrilled as I was when I captured my first.



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All offers are subject to availability, prices and specifications are subject to change without notice. E&O.E.
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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

JULY 2021

THREE SHADOW TRANSITS!

Observe the shadows cast on Jupiter's atmosphere by Ganymede, Callisto and Io

LUNAR LETTERS

Spot the clair-obscur effects that reveal an 'X' and a 'V' on the Moon

FINDING PLUTO

Can you track down and image the dwarf planet?

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- ✦ An evening conjunction of Mars and Venus
- ✦ Noctilucent clouds, and how to spot them
- ✦ A thin crescent Moon with Mercury, then Venus

Red light friendly

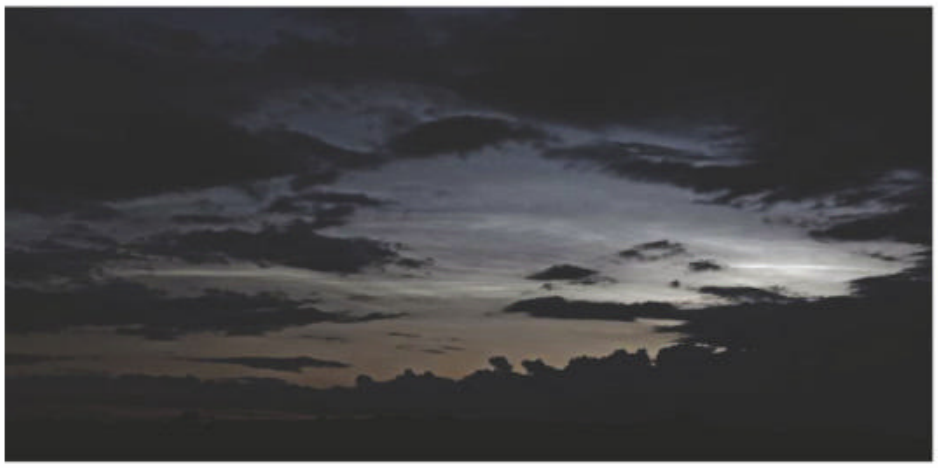
To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JULY HIGHLIGHTS

Your guide to the night sky this month



◀ All month

Noctilucent clouds (NLCs) may be visible this month. If present, they can typically be seen 90–120 minutes after sunset low above the northwest horizon, or a similar time before sunrise low above the northeast horizon. To discover more about NLCs, turn to page 47.

Sunday 4

Mercury reaches greatest western elongation today, appearing 21.6° from the Sun in the morning sky. Despite this, Mercury has a poor position in the sky, rising a little over one hour after the Sun.

Tuesday ▶ 6

This morning's 13%-lit waning crescent Moon lies 5.8° south of the Pleiades open cluster. Moonrise is approximately 2.5 hours before sunrise at around 02:20 BST (01:20 UT).

Thursday 8

Early risers will be treated to a thin, 3%-lit waning crescent Moon lying 2.9° north of mag. +0.1 Mercury. Look for the pair low above the northeast horizon approximately one hour before sunrise.

Sunday 11

This evening's Moon has a 3%-lit waxing phase and sits 7.3° to the right of bright Venus, visible low in the west-northwest shortly after sunset. Venus and Mars are now a fraction over 1° apart.

Monday 12

View Venus with a crescent Moon after sunset this evening.

Callisto's shadow is in transit from 22:48 BST (21:48 UT) until 03:32 BST (02:32 UT). Jupiter will rise after it starts. To read more, see page 47.

Saturday 17

Ganymede's shadow will be in transit across Jupiter's disc from 23:40 BST (22:40 UT) until 03:17 BST (02:17 UT). The moon begins its transit from 02:53 BST (01:53 UT). See page 47 for more details.

Monday 19

The mag. +12.6 comet 4P/Faye sits 1° north of mag. +5.8 Uranus in the morning sky.

Saturday ▶ 24

Tonight's full Moon lies 5.5° southeast of mag. +0.4 Saturn.

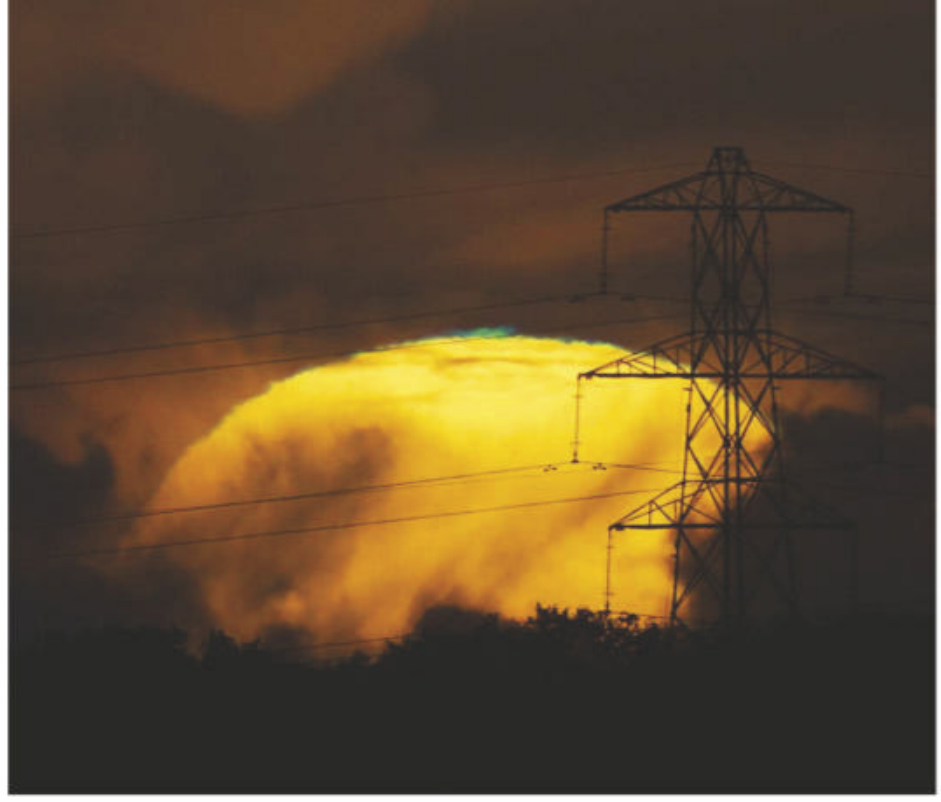
Family stargazing

Saturn is approaching a time that is optimal for viewing and although it appears low when it's viewed from the UK, a small telescope will show its rings. Locate Saturn rising above the southeast horizon as darkness falls; brighter Jupiter can be seen rising around 50 minutes later. Allow Saturn to gain some height above the horizon and then centre it in your field of view. A minimum magnification of 25x will show the rings extending either side of the main globe, while magnifications of 50x to 75x will give a sense that the rings are actually circling the planet. **www.bbc.co.uk/cbeebies/shows/stargazing**

Wednesday ▶ 28

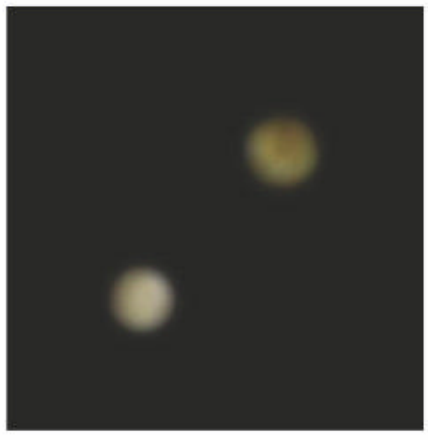
Saturn reaches opposition on 2 August, so now is a good time to observe the planet's rings starting to brighten – due to the Seeliger effect.

PETE LAWRENCE X 7



Monday ▶

5 Earth is at its furthest point from the Sun at 23:27 BST (22:37 UT). At this aphelion position our planet will lie 152,100,527km from its star. As a consequence, if you're into solar imaging, the apparent size of the Sun's disc will be at its smallest for the year.



◀ Friday

9 A glance at Jupiter through a telescope will show Io and Europa close to one another, just 3 arcseconds apart, at 02:43 BST (01:43 UT). See page 47.

Catch a thin (less than 1%-lit) Moon rising in the northeast about an hour before sunrise.

Saturday

10 This evening a thin waxing crescent Moon is visible over the northwest horizon.

Venus follows the Moon, visible in the west-northwest. As the sky darkens, look for mag. +1.8 Mars, 1.6˚ from Venus.

Tuesday

13 As the Moon moves to the east, now shining as a 14%-lit waxing crescent, Venus and Mars are at their closest in the evening twilight, low above the west-northwest horizon. This evening they are just 0.5˚ apart.

Sunday

25 Ganymede's shadow begins to transit Jupiter's disc from 03:44 BST (02:44 UT). See page 47 for details.

As 95%-lit waning gibbous Moon lies 5.5˚ to the south of mag. –2.6 Jupiter.

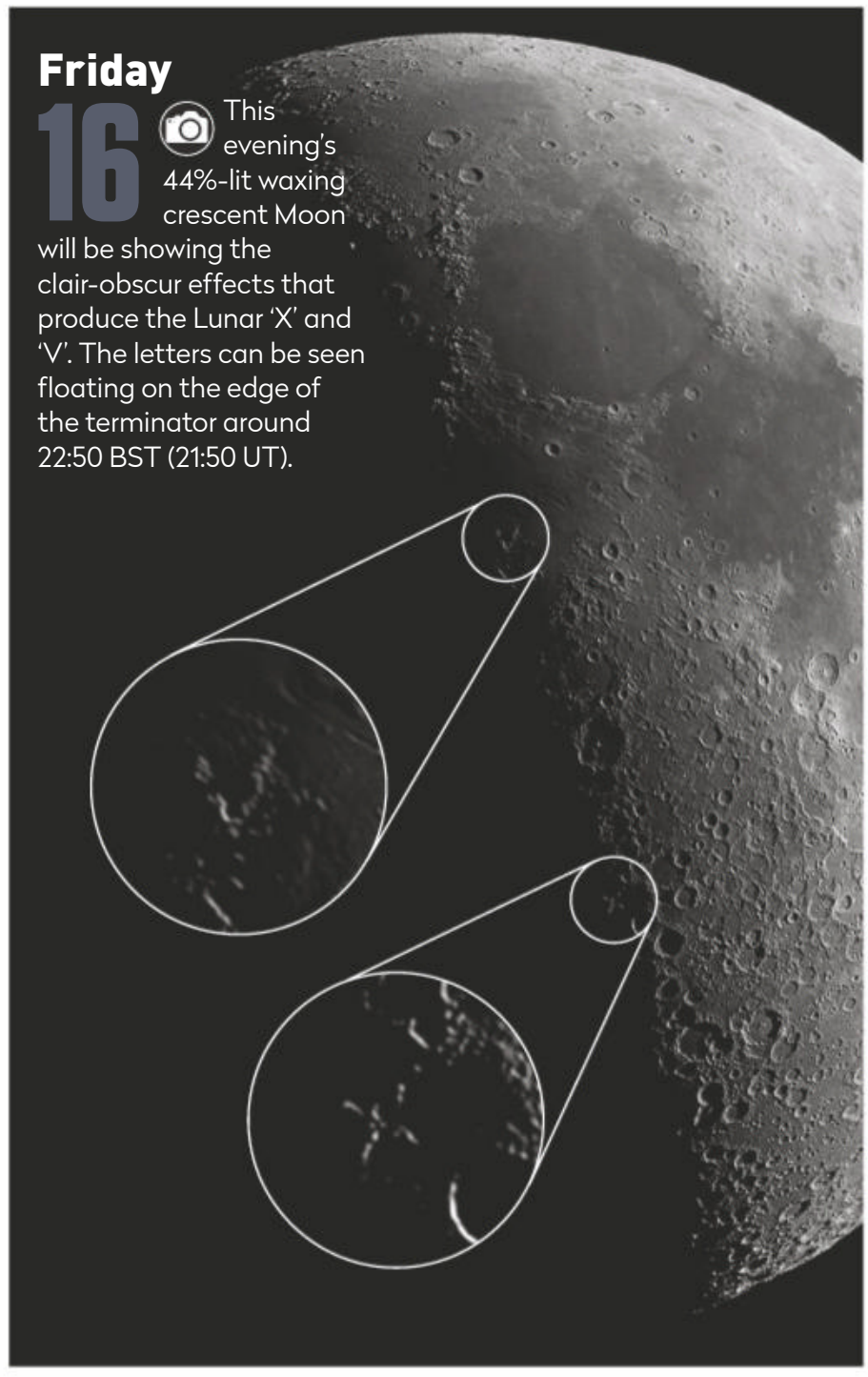
Thursday

29 See Callisto, Io and Io's shadow in transit on Jupiter's disc this evening. Turn to page 47 for details.

The peak of the Southern Delta Aquariid meteor shower. A 64%-lit waning gibbous Moon will interfere.

Friday

16 This evening's 44%-lit waxing crescent Moon will be showing the clair-obscur effects that produce the Lunar 'X' and 'V'. The letters can be seen floating on the edge of the terminator around 22:50 BST (21:50 UT).



NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

THIN MOONS

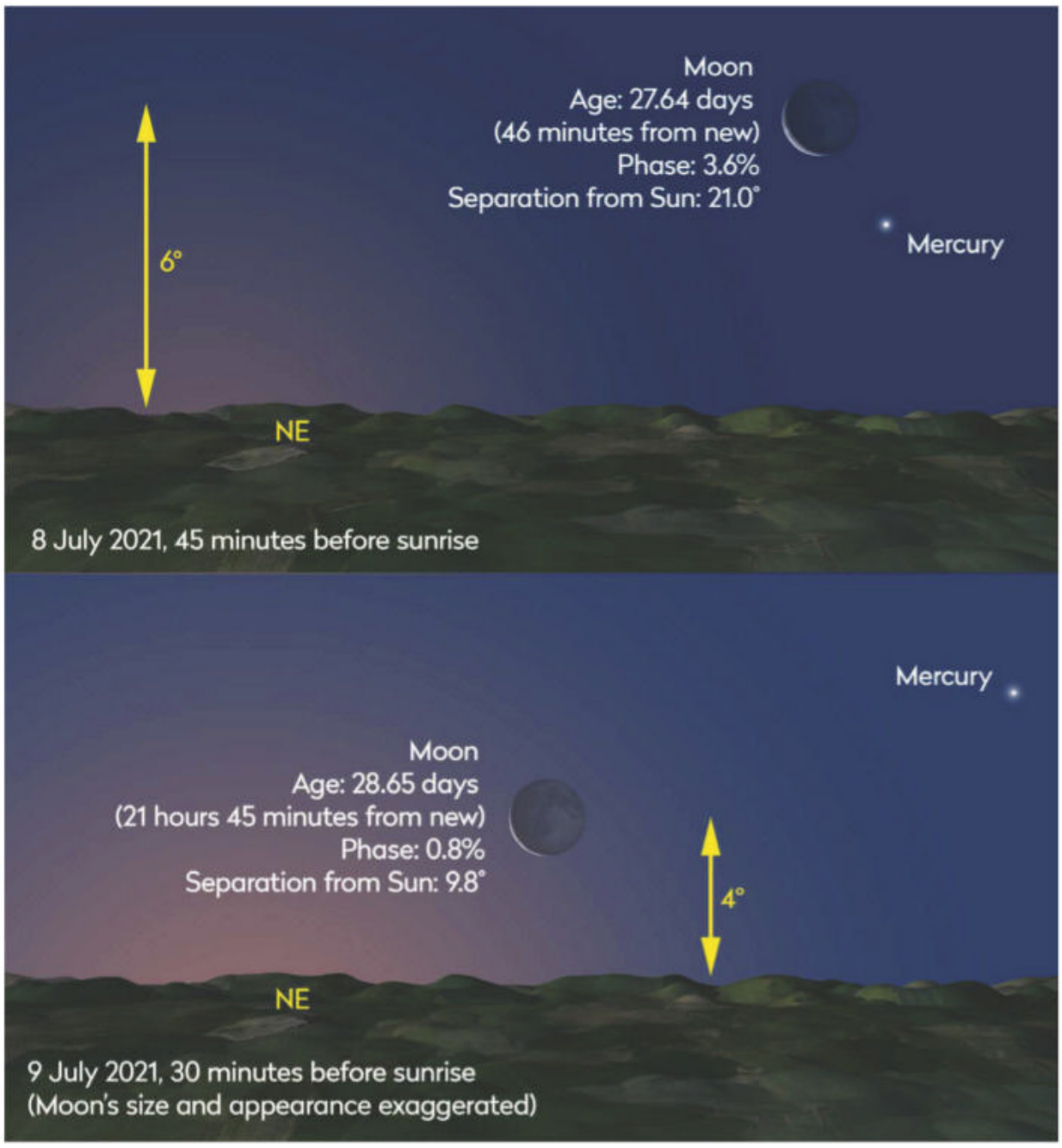
BEST TIME TO SEE:
8 & 9 July (morning sky before sunrise)
10 July (evening sky after sunset)

There are several well-timed opportunities for spotting thin Moons this year – waxing or waning lunar crescents seen close to the Moon's new phase. At new Moon, the Moon lines up with the Sun when seen from Earth – technically they have the same ecliptic longitude. The ecliptic is that great circle centred on Earth which represents our planet's orbital plane projected onto the sky. It also describes the path of the Sun against the background stars.

The zero point for ecliptic longitude is called the 'first point of Aries' and it's marked by the intersection of the ecliptic and the celestial equator. The Sun is positioned here at the March equinox.

A fortuitous timing of the Moon's new phase means its disappearance from the morning sky as a waning lunar crescent, or reappearance in the evening sky as a waxing lunar crescent, may be observed quite soon before or after the Moon and Sun reach the same ecliptic longitude.

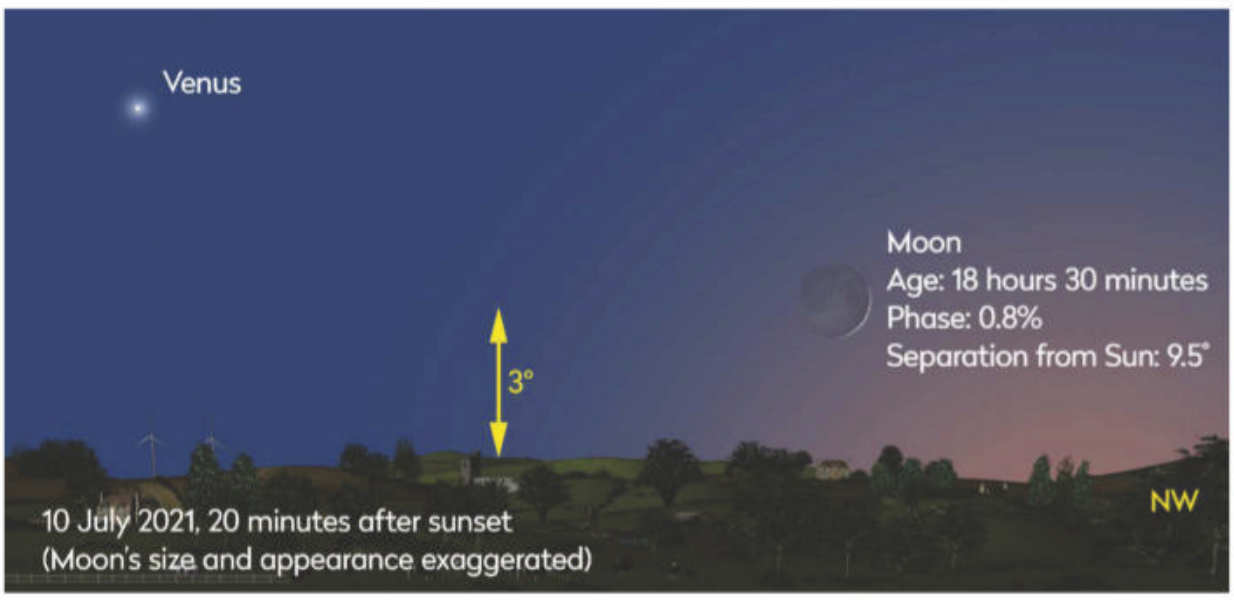
Around new Moon, the separation between the Moon and the Sun decreases, reaches a minimum at new Moon, and then increases again. There's a theoretical, minimum separation called the 'Danjon limit', which predicts a lunar crescent is unlikely to be seen when it's less than 7° from the Sun. This limit takes into account that the Moon's surface is not smooth, but rough and textured. When it gets close to the Sun, the hills, mountains, craters and valleys on the Moon's limb cause what would be a very thin arc of Moon to break up and become virtually invisible.



▲ **See a conjunction of the thin crescent Moon and Mercury on the mornings of 8 and 9 July**

The next chance for thin Moon spotting is on the 8th, when it's in the morning sky as a 3.6%-lit waning lunar crescent. It will appear 2.9° to the north of mag. +0.1 Mercury, low above the northeast horizon about an hour before sunrise. On the 9th it may be possible to see the Moon at 0.8%-lit phase, low above the northeast horizon, rising an hour before sunrise.

On the evening of 10 July, the Moon may be seen as a 0.6%-lit waxing crescent, setting just 1 hour after the Sun, this time behind the northwest horizon. Next, on the evening of 11 July, the Moon will appear as a 3.3%-lit waxing crescent, 7.3° to the right of bright Venus (as seen from the UK), visible low above the west-northwest horizon just after sunset. As the evening twilight darkens, look for mag. +1.8 Mars located 1.6° from mag. –3.8 Venus.



▲ **On 10 July the Moon appears near Venus, low above the west-northwest horizon**

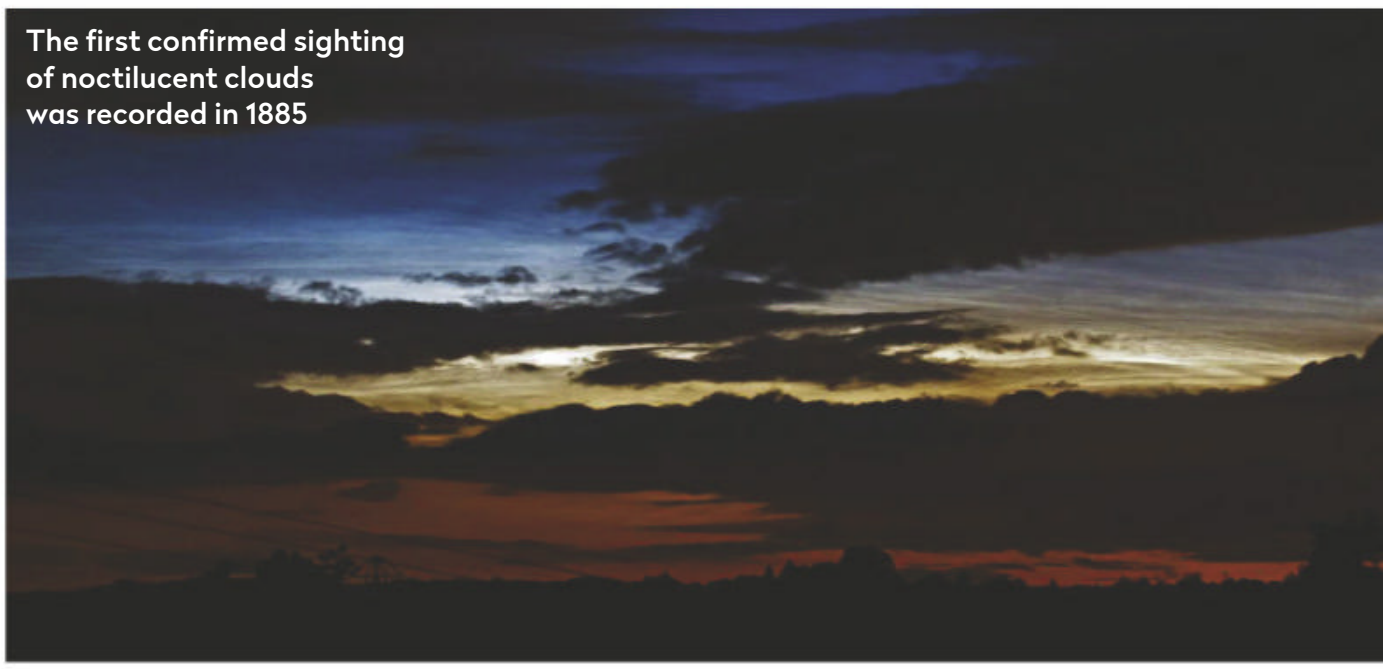
ALL PICTURES: PETE LAWRENCE

Noctilucent cloud season – part 2

BEST TIME TO SEE: All month

From mid-northern latitudes, for several weeks either side of the June solstice, it may be possible to spot a rare phenomenon known as noctilucent clouds (NLCs). These are high altitude ice clouds, the highest clouds on Earth, forming in a narrow layer 82km up in the mesosphere. At this height in the atmosphere, when the Sun is between 6 and 16° below the horizon as seen from the ground, sunlight reflects from the tiny ice crystals that NLCs consist of and they become visible. Existing on the edge of space, NLCs are seeded by the tiny fragments that result from meteoroids vaporising in our atmosphere.

Shining on the edge of twilight, NLCs can glow dramatically against the dark backdrop of the night sky, hence their name, noctilucent or 'night-shining' clouds. If present, they may be seen typically 90-120 minutes after sunset low above the northwest horizon, or a similar time before sunrise low above the northeast horizon.



The first confirmed sighting of noctilucent clouds was recorded in 1885

This is a rule of thumb however and in recent years there have been exceptions. Last year, a big display started to become visible after sunset above the northeast and north horizon. In addition, although NLCs are normally described as a low-level phenomenon – requiring a low, clear northern horizon to see them – there have been reports over recent years of NLCs creeping to higher altitudes.

NLCs usually shine with a white-blue colour and often exhibit fine sinuous detail. Herringbone patterns and knots are another characteristic of a complex display. Not all appearances are bright, though, and diffuse, dim NLCs may also appear. NLCs are very photogenic and best shot with a wide-angle or mid-angle lens fitted to a camera on a tripod. Bright displays can also be imaged with smartphone cameras.

Jupiter moon events

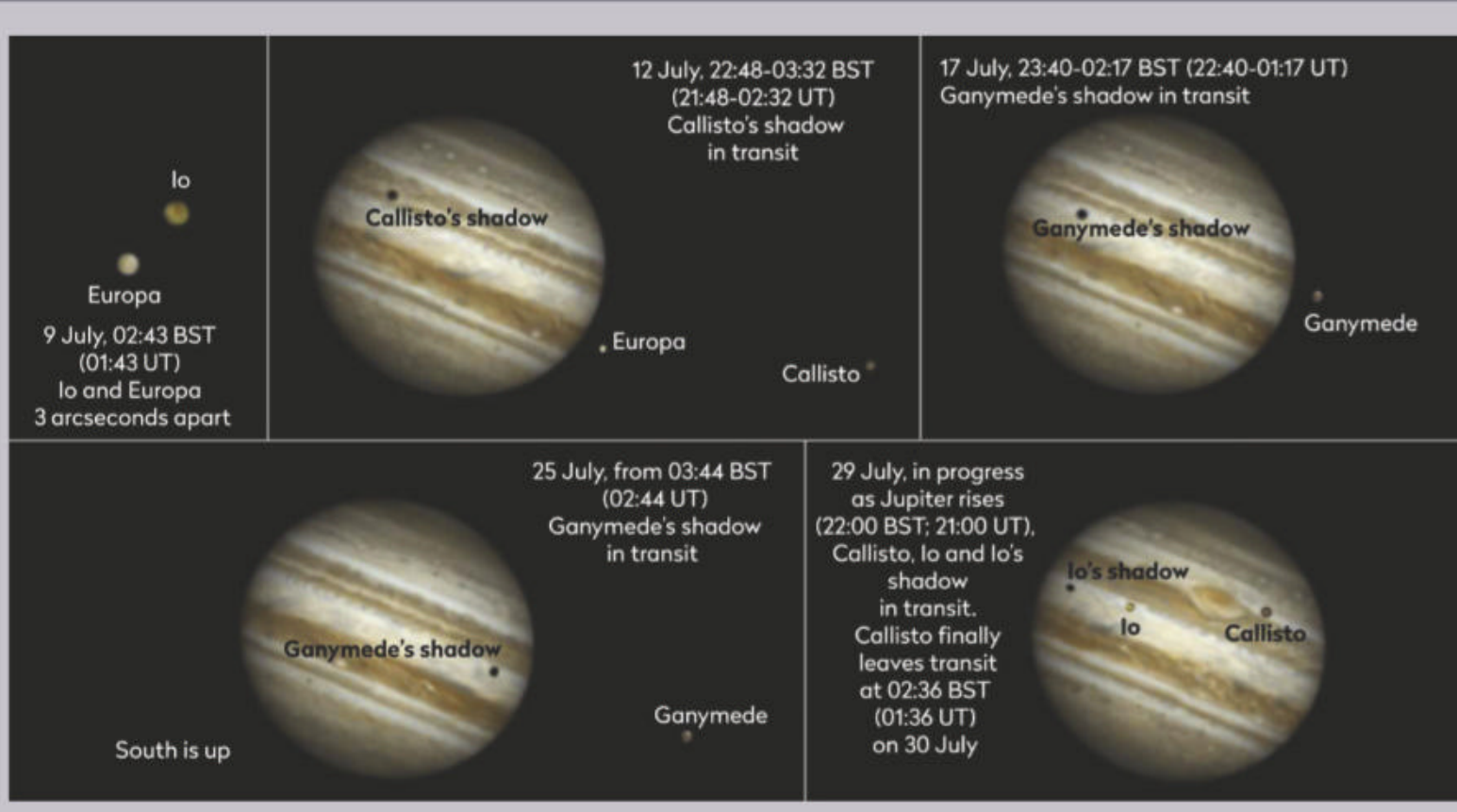
BEST TIME TO SEE:
9, 12, 17, 25 and 29 July at specified times

A group of Galilean moon interactions with Jupiter takes place this month.

On the 9th, Io and Europa appear separated by 3 arcseconds – the apparent size of Uranus. Closest separation is at 02:43 BST (01:43 UT).

On the 12th, Callisto's shadow transits Jupiter between 22:48 BST (21:48 UT) and 03:32 BST (02:32 UT). This begins before Jupiter rises and progresses as the gas giant gains altitude.

Ganymede's shadow transits on 17 and 25 July. The event on the 17th occurs between 23:40 BST (22:40 UT) and 02:17 BST (01:17 UT) on the 18th. Ganymede itself transits on the 18th from 02:53 BST (01:53 UT). The shadow transit on the 25th starts at 03:44 BST (02:44 UT).



▲ **View a month of wonderful displays by Jupiter's Galilean moons Io, Europa, Ganymede and Callisto**

On the 29th, a telescopic view of Jupiter just after rising will show two moons and a moon shadow in transit; Callisto and Io will be in transit along with Io's shadow. Io's shadow exits transit at 23:23 BST (22:23 UT), Io at 23:53 BST (22:53 UT). Callisto leaves Jupiter's disc at 02:36 BST (01:36 UT) on 30 July.

THE PLANETS

Our celestial neighbourhood in July

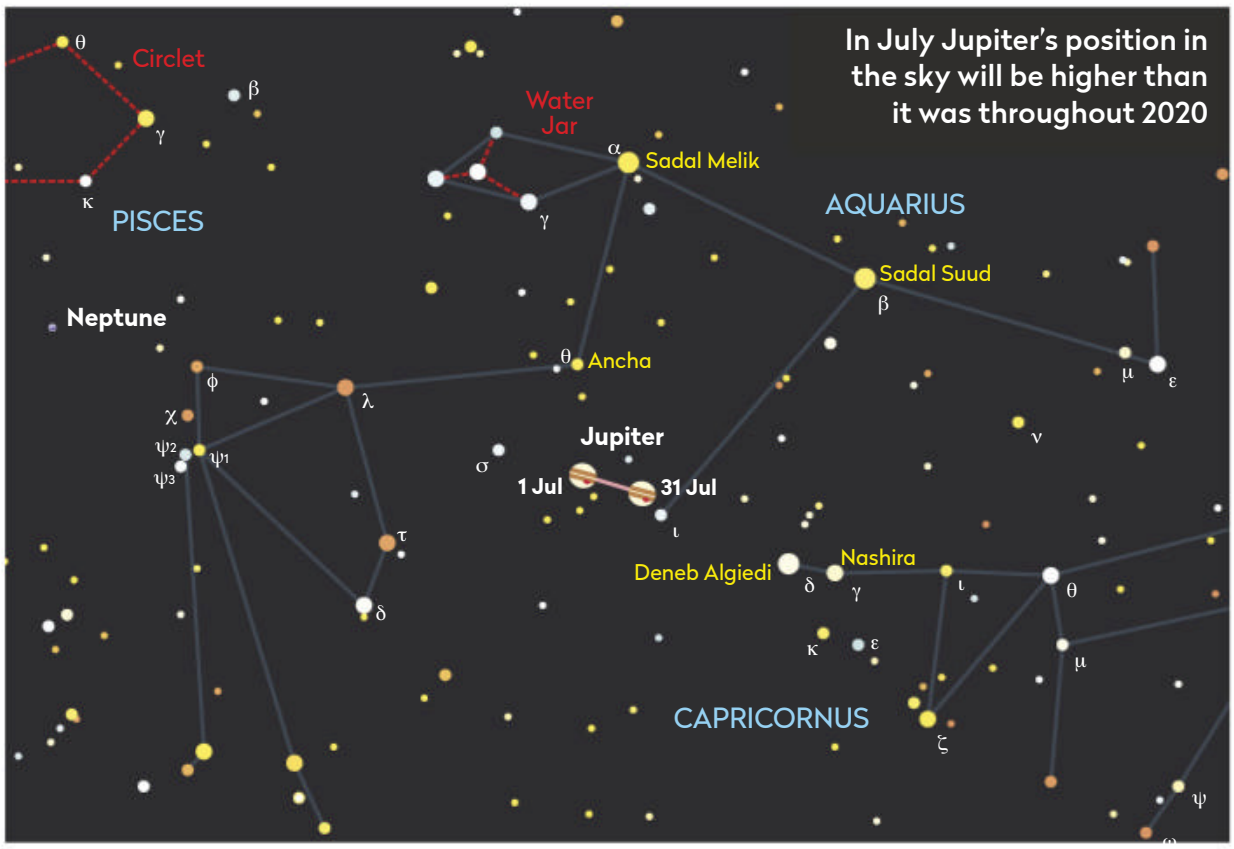
PICK OF THE MONTH

Jupiter

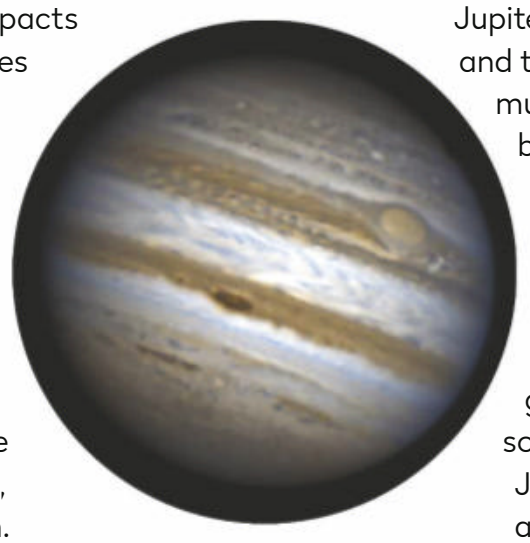
Best time to see: 31 July, 02:40 BST (01:40 UT)
Altitude: 24°
Location: Aquarius
Direction: South
Features: Complex, banded atmosphere, moons
Recommended equipment: 75mm or larger

Jupiter rises five hours before the Sun on 1 July and manages to reach a peak altitude of 25° at 04:50 BST (03:50 UT) in a bright pre-sunrise dawn sky. Although this may appear low, it's a considerable improvement over the 14 or so degrees Jupiter was able to achieve in 2020. Indeed, an increase in altitude of 10° can make a huge difference to the appearance of the planet through a telescope.

Two of the main effects that hinder viewing are reduced. The first is the result of the thicker layer of atmosphere between us and the planet when it's low down. As the planet rises higher, the thickness reduces and this translates directly to a reduction in the instability of the view. When viewed through a scope, Jupiter looks more stable when it's close to its highest position in the sky, due south.



Another effect that impacts low altitude objects comes from the atmosphere's ability to disperse light. Much like the way white light is spread into its component colours through a prism, the same happens with our atmosphere. The thicker the atmospheric layer the light has to pass through, the greater the dispersion. This manifests as colour fringing around a bright planet's edge; with red at the bottom and blue/green at the top. Jupiter's altitude will also reduce this.



▲ **Jupiter is approaching opposition, appearing at its best through a telescope on 31 July**

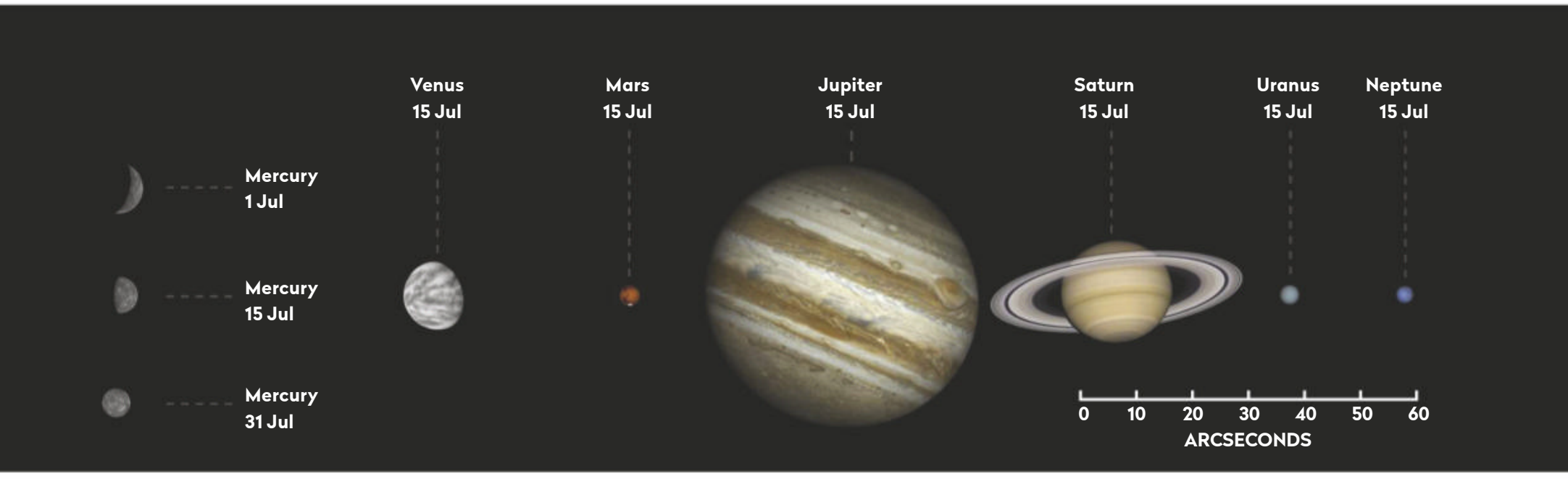
PETE LAWRENCE X 3

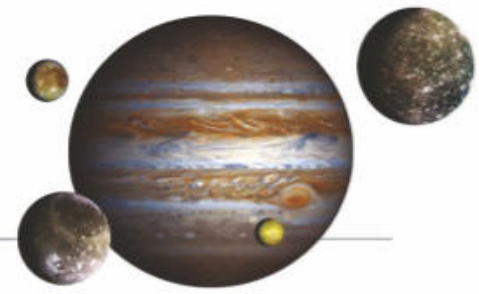
Jupiter is close to equinox and there are a number of mutual events visible between its moons as a result, the best of which we describe each month in this guide (see page 47).

A 94%-lit waning gibbous Moon sits 5° south of Jupiter on 26 July, when both objects are due south at 03:00 BST (02:00 UT). On the 31st, Jupiter reaches its highest position in the sky, due south, at 02:40 BST (01:40 UT) just after true darkness ends.

The planets in July

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 15 July, from 1 hour prior to sunrise
Altitude: 2° (very low), 5° 30 minutes before sunrise
Location: Gemini
Direction: Northeast

Mercury is a morning object, rising about an hour before the Sun on 1 July. It ascends in the northeast, shining at mag. +1.0 and showing an 8 arcsecond disc that is 27% lit. On 8 July a 3%-lit waning crescent Moon lies 2.9° to the north of the now mag. +0.2 planet. Mercury rises 80 minutes before the Sun from 8–15 July. Over the rest of the month, it heads nearer the Sun, rising 25 minutes before sunrise on the 31st. It also brightens and this should help to keep it visible: on the 15th it shines at mag. –0.6, increasing to mag. –1.6 on the 27th when it rises 45 minutes before the Sun.

Venus

Best time to see: 13 July, 22:00 BST (21:00 UT)
Altitude: 6.6° (low)
Location: Leo
Direction: West-northwest

Venus is an evening planet, suffering due to poor placement. Shining at mag. –3.9, it sets 1.5 hours after the Sun on 1 July, a figure reducing to 70 minutes after the Sun on 31 July. It lies 30 arcminutes from mag. +1.9 Mars on 13 July.

Mars

Best time to see: 13 July, 22:00 BST (21:00 UT)
Altitude: 6.6° (low)
Location: Leo
Direction: West-northwest

Mars appears tiny through the eyepiece, less than 4 arcseconds across. It is struggling to keep ahead of the evening twilight and is barely visible in the west-northwest after sunset. At mag. +1.8, Mars is outshone by Venus, which passes half-a-degree to its north on the 13th.

Saturn

Best time to see: 31 July, 01:30 BST (00:30 UT)
Altitude: 18°
Location: Capricornus
Direction: South

Saturn is a morning planet, which is able to reach its highest position above the southern horizon in relative darkness in July. Opposition occurs on 2 August and the end of July is a time when its rings should be starting to increase in brightness due to the opposition effect. A full Moon sits to the southeast of Saturn on the night of 24/25 July.

Saturn increases in brightness by a small amount: on the 1st it shines with an off-white, straw-yellow hue at mag. +0.4 and by July's close it increases to mag. +0.2.

Uranus

Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 22°
Location: Aries
Direction: East

Uranus is slowly crawling away from the Sun but is not well positioned at the moment. It does manage to reach an altitude of 22° above the eastern horizon under dark-sky conditions by the month's end.

Neptune

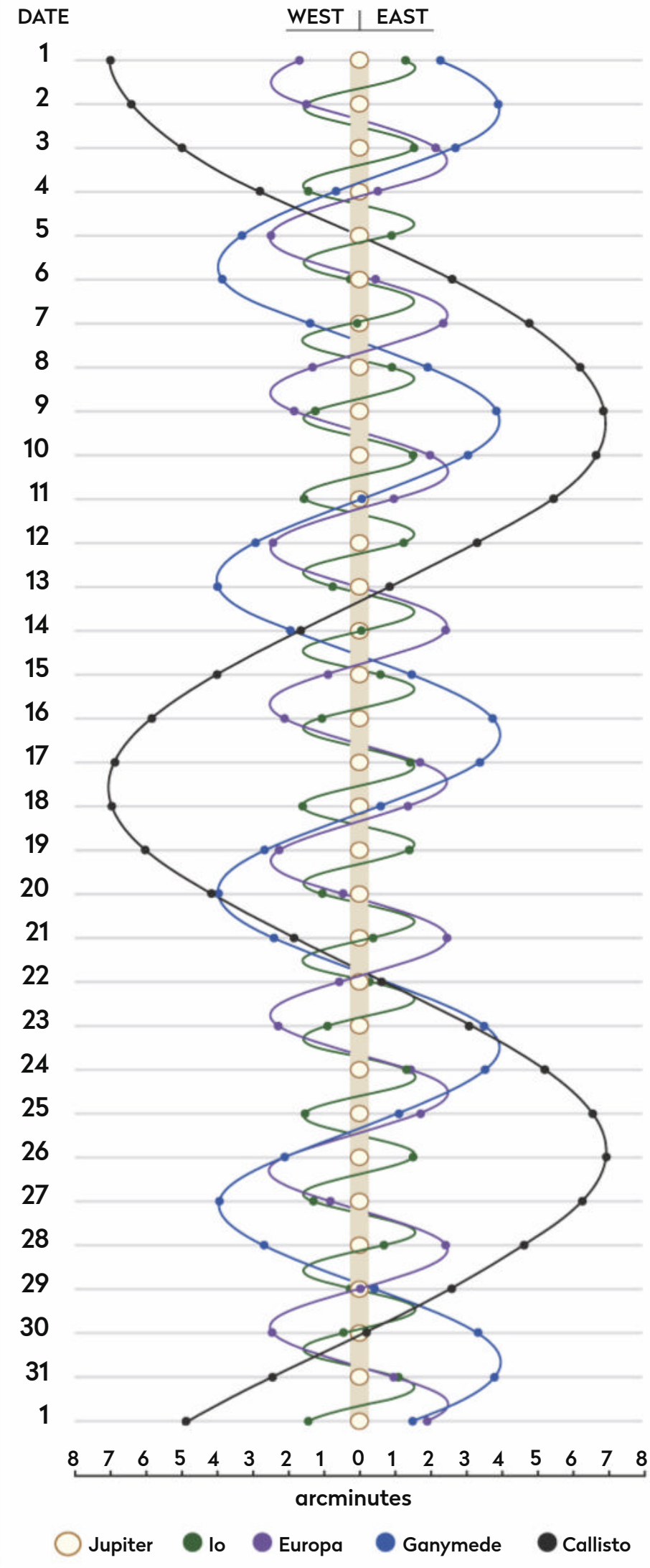
Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 29°
Location: Aquarius
Direction: South-southeast

Neptune may be seen under dark-sky conditions towards the month's end, although it isn't able to achieve its highest altitude due south. Neptune is in Aquarius, close to the border with Pisces; find it south of the Circlet asterism in Pisces.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JULY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JULY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW (5°, N, E, S, W)
- MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

1 July at 01:00 BST
15 July at 00:00 BST
31 July at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in July*

Date	Sunrise	Sunset
1 Jul 2021	04:46 BST	21:42 BST
11 Jul 2021	04:56 BST	21:35 BST
21 Jul 2021	05:09 BST	21:23 BST
31 Jul 2021	05:24 BST	21:07 BST

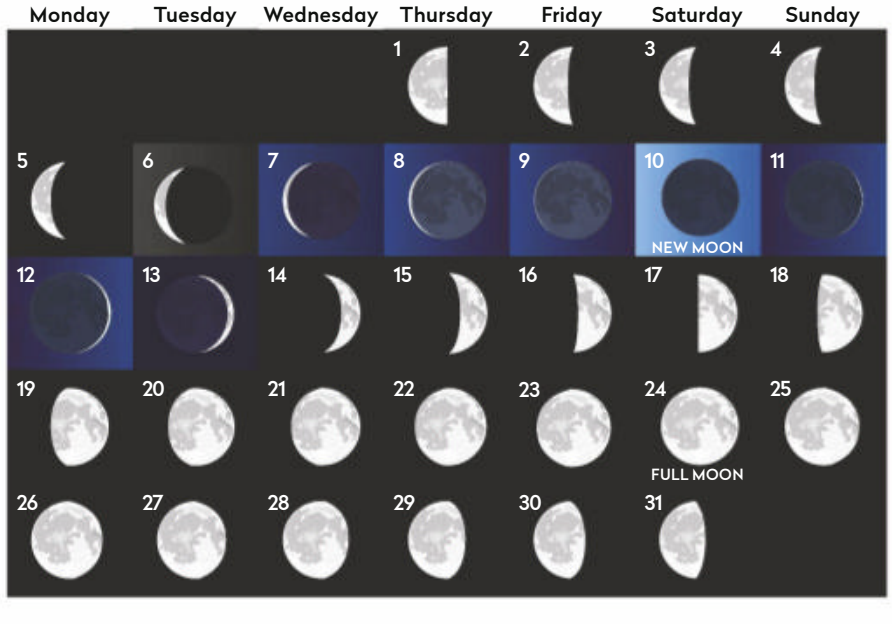
Moonrise in July*

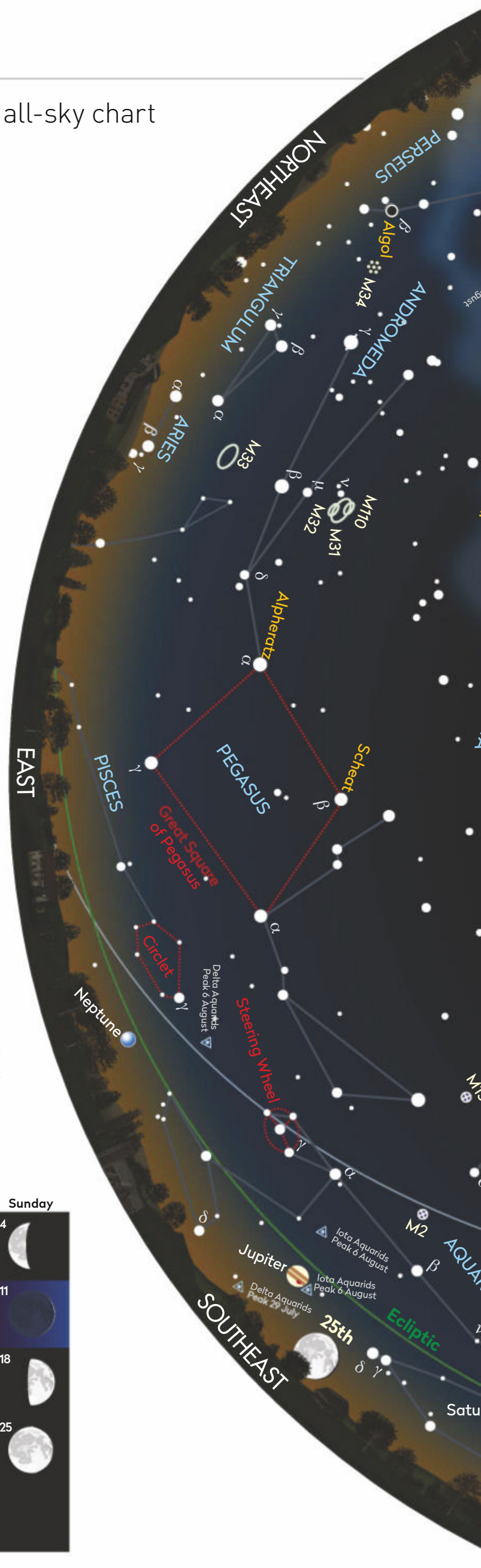
Moonrise times

1 Jul 2021, 01:05 BST	17 Jul 2021, 13:51 BST
5 Jul 2021, 01:56 BST	21 Jul 2021, 19:38 BST
9 Jul 2021, 03:50 BST	25 Jul 2021, 22:38 BST
13 Jul 2021, 08:25 BST	29 Jul 2021, 23:35 BST

*Times correct for the centre of the UK

Lunar phases in July





MORE **ONLINE**

Paul and Pete's night-sky highlights

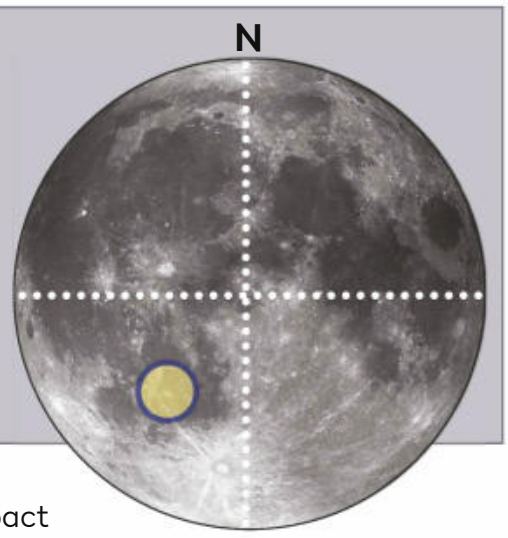
Southern Hemisphere sky guide

MOONWATCH

July's top lunar feature to observe

Bullialdus

Type: Crater
Size: 61km
Longitude/Latitude: 22.3°W, 20.7°S
Age: 1.1-3.2 billion years
Best time to see: Two days after first quarter (19 July) or one day after last quarter (3 & 4 July)
Minimum equipment: 50mm telescope



Bullialdus is a superb example of an impact crater. It sits within the western regions of 750km **Mare Nubium** and appears largely surrounded by dark, solidified lava. The closest neighbour is 26km **Bullialdus A**, which sits immediately south-southeast of Bullialdus, the rims of both features virtually touching. Apart from that, 61km Bullialdus is clear of any real intrusions, allowing it to appear framed in all its glory.

The crater is extremely well preserved, with an appearance that is reminiscent of the impressive form of 93km Copernicus further to the north. The comparison really is well founded: Bullialdus shows the same multi-terraced rim structures, flat floor and distinct central mountain complex as Copernicus, just at two-thirds the scale.

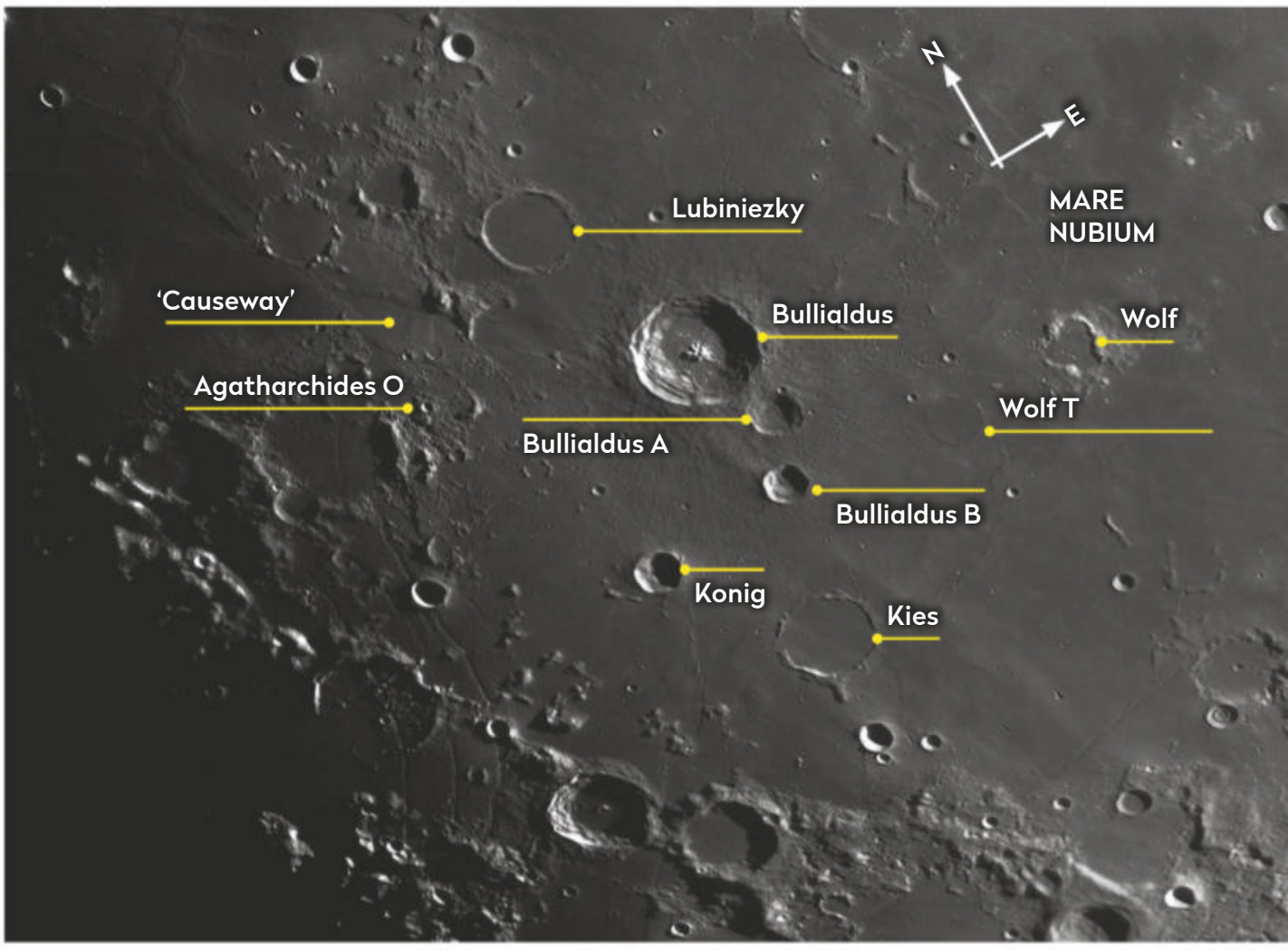
Comparing both craters also provides an understanding of how things change on the Moon's surface over time. Copernicus is a relatively new feature on the lunar landscape, its age estimated to be less than 1.1 billion years. The age of Bullialdus lies somewhere between 1.1 to 3.2 billion years, a fairly sizeable range, making Bullialdus the older feature. When you look at both craters visually, Copernicus is striking because it has a massive series of bright rays emanating away from it. The material forming the rays was ejected when whatever made Copernicus hit the lunar surface. These rays look bright and relatively fresh, but over time they will fade. Bullialdus is old enough for this fading process to have already happened, and it's not immediately evident where its rays are. Bright material crossing Mare Nubium tends to be belong to another young crater, 86km Tycho, some way to the southeast.

Bullialdus has a depth of around 3.5km and its central mountain complex contains peaks which rise almost a kilometre above the crater's floor. Surrounding the slightly polygonal shape of Bullialdus's rim is an impressive ring of ejecta ramparts. These rise up to the crater's rim edge and are dotted with small craterlets. A series of radial ridges and valleys emanate from Bullialdus across the ramparts.

A number of interesting features can be found in the surrounding area. North-northwest lies the impressive ring of 45km **Lubiniezky**. This crater appears to be all rim, its floor flooded and smooth apart from a number of small craterlets. Immediately west of Lubiniezky lies a highland complex with what looks like the remains of the northern rim of a lost crater. Continue west to a distinct 7km horseshoe feature, a crater that has been flooded from the north, its northern rim lost to lava. Next, if you look to the west a little farther, you'll arrive at the bright, 5km ray crater **Agatharchides O**. Slightly to the north of this crater is a curious elevated band of lava dubbed the **'Causeway'**.

Surrounding Bullialdus's rim is an impressive ring of ejecta ramparts

Copernicus has its celebrated 'ghost crater', 70km Stadius, nearby, and Bullialdus also has such a feature. In keeping with its reduced scale compared to Copernicus, its ghost is smaller. Known as **Wolf T**, this 26km feature is barely visible, its rim and floor virtually co-incident with the surface of Mare Nubium. To locate it, look 120km to the southeast of the centre of Bullialdus.



▼ **An exploration of features around Bullialdus reveals the 26km 'ghost' crater Wolf T and 5km ray crater Agatharchides O**

PETE LAWRENCE X 3

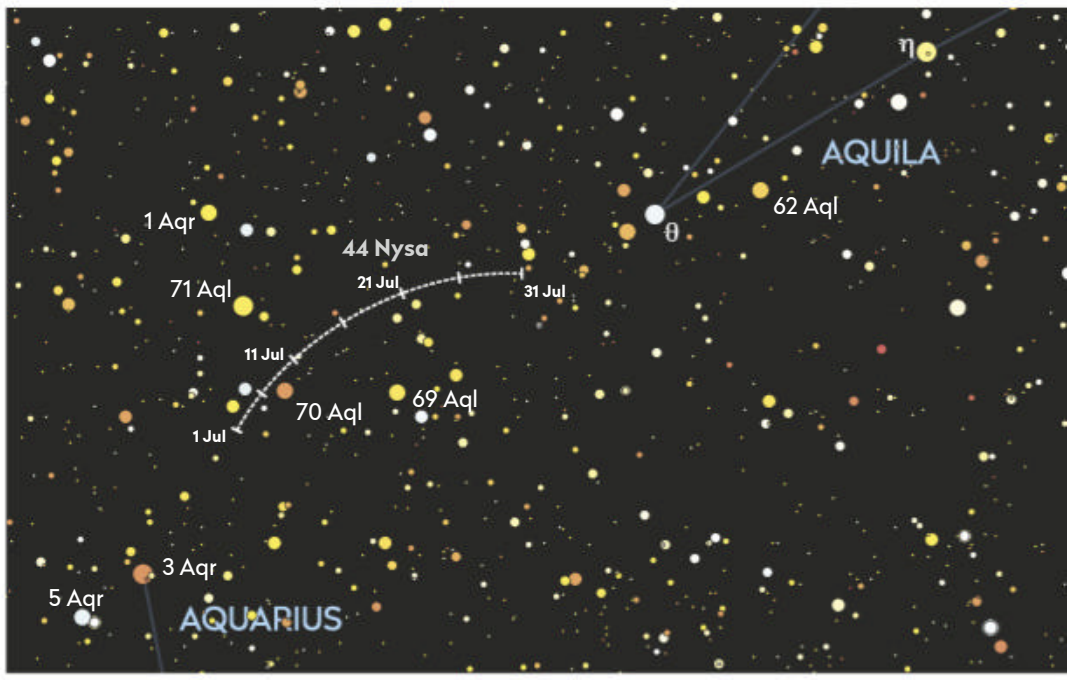
COMETS AND ASTEROIDS

Observe Asteroid 12 Victoria as it reaches opposition in Aquila, the Eagle

Minor planet 12 Victoria reaches opposition this month. On 1 July, it shines at mag. +9.3, slowly brightening over the rest of the month to a peak of mag. +8.8 at opposition on the 30th. This makes it an ideal object to find and track with a small telescope.

On 1 July, 12 Victoria is located in northwest Aquarius, close to the border with Aquila. This region lacks any really bright stars, the best guides are the mag. +4.4 star 3 Aquarii and 70 Aquilae at mag. +4.9. On the 1st, 12 Victoria sits two-thirds of the way along a line from 3 Aquarii towards 70 Aquliae. Its path arcs as it tracks northwest. At its brightest, near the month's close, it lies about 2.5° east and a fraction south of mag. +3.2 Theta (θ) Aquilae. The best way to identify 12 Victoria is to sketch or image the field you suspect the asteroid to be located within over the course of several nights. If 12 Victoria is in this field, its movement will reveal it. (In order to achieve this, the field must be recorded with field stars below the threshold of the asteroid, say at least mag. +9.5.)

12 Victoria was discovered on 13 September 1850 by John Russell Hind. Although officially named after the Roman goddess of victory, it was also named in honour of Queen Victoria. It's a siliceous or stony (S-type) asteroid, around 120km-across, orbiting



▲ **Track 12 Victoria's progress over July with a small telescope**

within the main belt between Mars and Jupiter. Its apparent magnitude varies between +8.7 and +12.8, making this opposition quite favourable. 12 Victoria's orbit takes it out as far as 2.85 AU and in as close as 1.82 AU from the Sun. Studies of its elongated shape suggest that it might be a binary object, the primary chunk having an irregular shaped moon in mutual orbit around it.

STAR OF THE MONTH

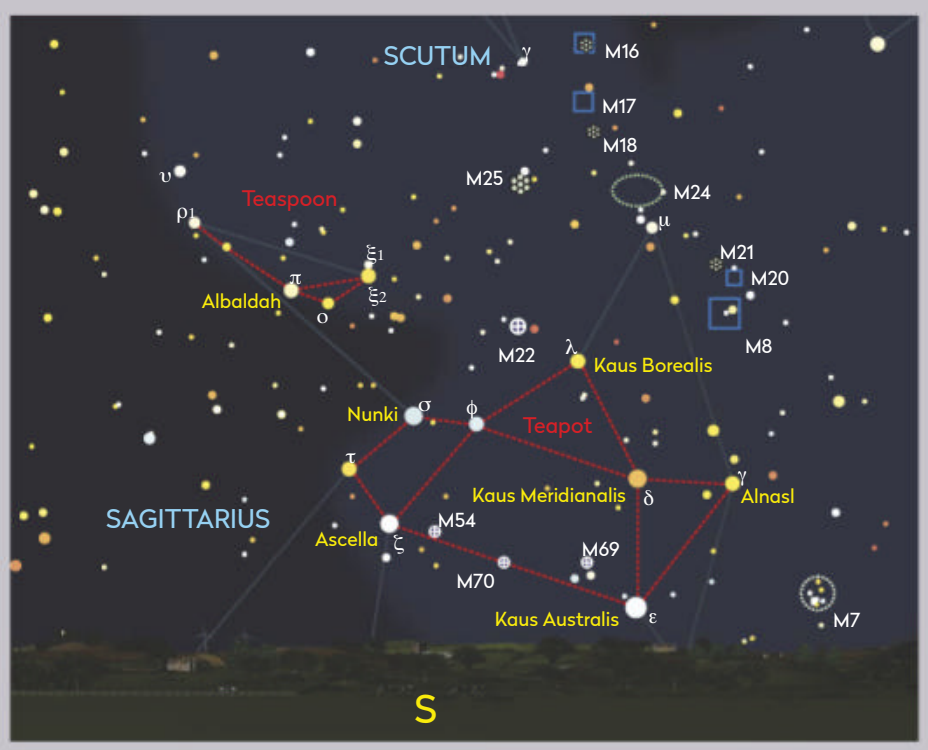
Nunki, a bright gem in the Teapot asterism

A familiar asterism in the Northern Hemisphere's summer sky is the Teapot. It's found in the northern part of the constellation of Sagittarius, the Archer, the southern half never rising above the UK's horizon. The Teapot's spout lies to the west, or right as we see it from the UK. The handle, unsurprisingly sits to the east, or left. Nunki (Sigma (σ) Sagittarii) is the brightest star of the four stars that form the handle's outline, and it's the second brightest in Sagittarius, after Kaus Australis (Epsilon (ε) Sagittarii). Nunki marks the northeast corner of the handle, and shines at mag. +2.0.

Nunki is a B-type main sequence dwarf star of spectral type B2.5 V. The V identifies its dwarf status, the same as our own Sun, which has a spectral type of G2 V. In the case of Nunki, its B class indicates it's a hot blue-white coloured star. The star is 228 lightyears away and shines with a luminosity equivalent to 3,300 times that of our Sun.

Compared to Nunki, our Sun is quite cool. Our star's photospheric (surface) temperature is 5,505°C, while Nunki's is over three times higher at 18,617°C. Much of Nunki's light is radiated in the extreme ultraviolet part of the spectrum, placing it out of human visual range. It's a fast rotating star with a surface velocity of 165km/s. Again for

▼ **Nunki is the brightest of the four stars that form the Teapot's handle**



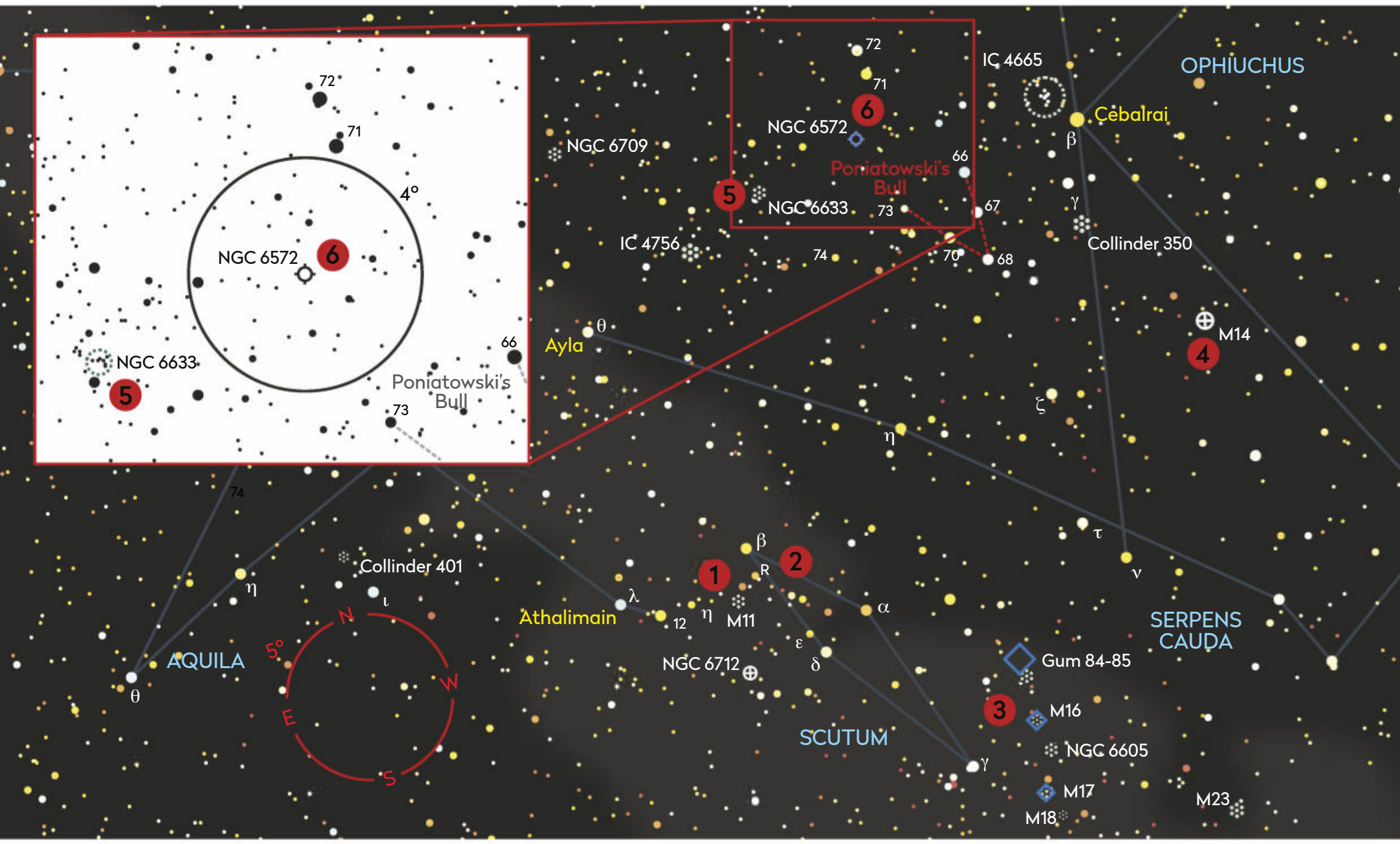
comparison, the Sun's is 2km/s.

Nunki is a normal star, fusing hydrogen to helium at its core. Modelling the star, it's possible to predict how long it's got left to burn and here, hotter is not always better. While the Sun is estimated to be about half way in its life cycle of 9 billion years, Nunki is 31.4 million years old and only expected to last another 50 million years.

BINOCULAR TOUR

With Steve Tonkin

Our wide-field targets range from the easy Wild Duck Cluster to the tricky NGC 6572



1. The Wild Duck Cluster

10x 50 You'll find the Wild Duck Cluster, M11, 2° to the southeast of Beta (β) Scuti. In your 10x50 binoculars you'll see a bright, slightly wedge-shaped glow, which could initially be mistaken for a globular cluster. It is one of the better objects for small binoculars, but don't expect them to resolve the V-shape of brighter stars that gives this cluster of a thousand or so stars its common name. ☐ **SEEN IT**

2. R Scuti Star Chain

10x 50 You may have noticed an orange star between Beta (β) Scuti and M11; that is R Scuti. It marks the northeast end of a 4° long chain of nine brighter stars that stretches to Alpha (α) Scuti. As your eyes become accustomed to the scene, you'll notice that many have fainter companions and that chains of fainter stars create a beautiful star field, with vibrant colours ranging from deep orange to brilliant blue-white. ☐ **SEEN IT**

3. The Eagle Nebula

10x 50 We find the Eagle Nebula, M16, 2.5° west of Gamma (γ) Scuti. You won't see the 'Pillars of Creation', made famous by the Hubble Space Telescope image, but you will see the cluster of stars that is forming from it. If you have an O-III or UHC filter, try putting it over an eyepiece and it may reveal the nebulous shape of the wings and tail from which this object gets its common name. ☐ **SEEN IT**

4. M14

15x 70 Our next target, the globular cluster M14, lies 6° west of Zeta (ζ) Serpentis and is quite easy to identify, even in July's all-night twilight. With averted vision, it will appear to increase in size and brightness. If you try mounted binoculars, you may notice a slightly triangular appearance: an optical illusion that is caused by faint strings of stars which seem to run from the southeast and southwest periphery of the cluster. ☐ **SEEN IT**

5. Graff's Cluster and NGC 6633

10x 50 These contrasting clusters fit into the same field of view. The 52 arcminute-wide lustre of Graff's Cluster is 3° west of Alya (Theta (θ) Serpentis). It's about 1,600 lightyears away. The brighter NGC 6633, with its four brightest stars glinting against the 20-arcminute gleam of the unresolved stars, is another 3° further on. NGC 6633 is 1,226 lightyears away. ☐ **SEEN IT**

6. NGC 6572

15x 70 Another 3° beyond NGC 6633 lies a challenge, the planetary nebula NGC 6572. At mag. +8.1, it is easily bright enough to be visible, but is less easy to identify, so we've provided a detailed finder chart (see inset). Do you notice any colour? Unless you have a good sky, it's difficult. You'll have to use direct vision and a lot of patience, but you may be rewarded with a hint of turquoise. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you track down and capture the remote dwarf planet Pluto?

Pluto is the planet that lost its planetary status in August 2006. With the increasing number of large bodies discovered in the outer Solar System, the International Astronomical Union (IAU) faced a problem. Should these objects be classified as planets too? In the end the IAU redefined what it means to be a planet and Pluto didn't make the grade. However, it did become the largest member of a new class of objects known as 'dwarf planets'. Reaching opposition this month, dwarf planet Pluto makes a great subject for our monthly challenge.

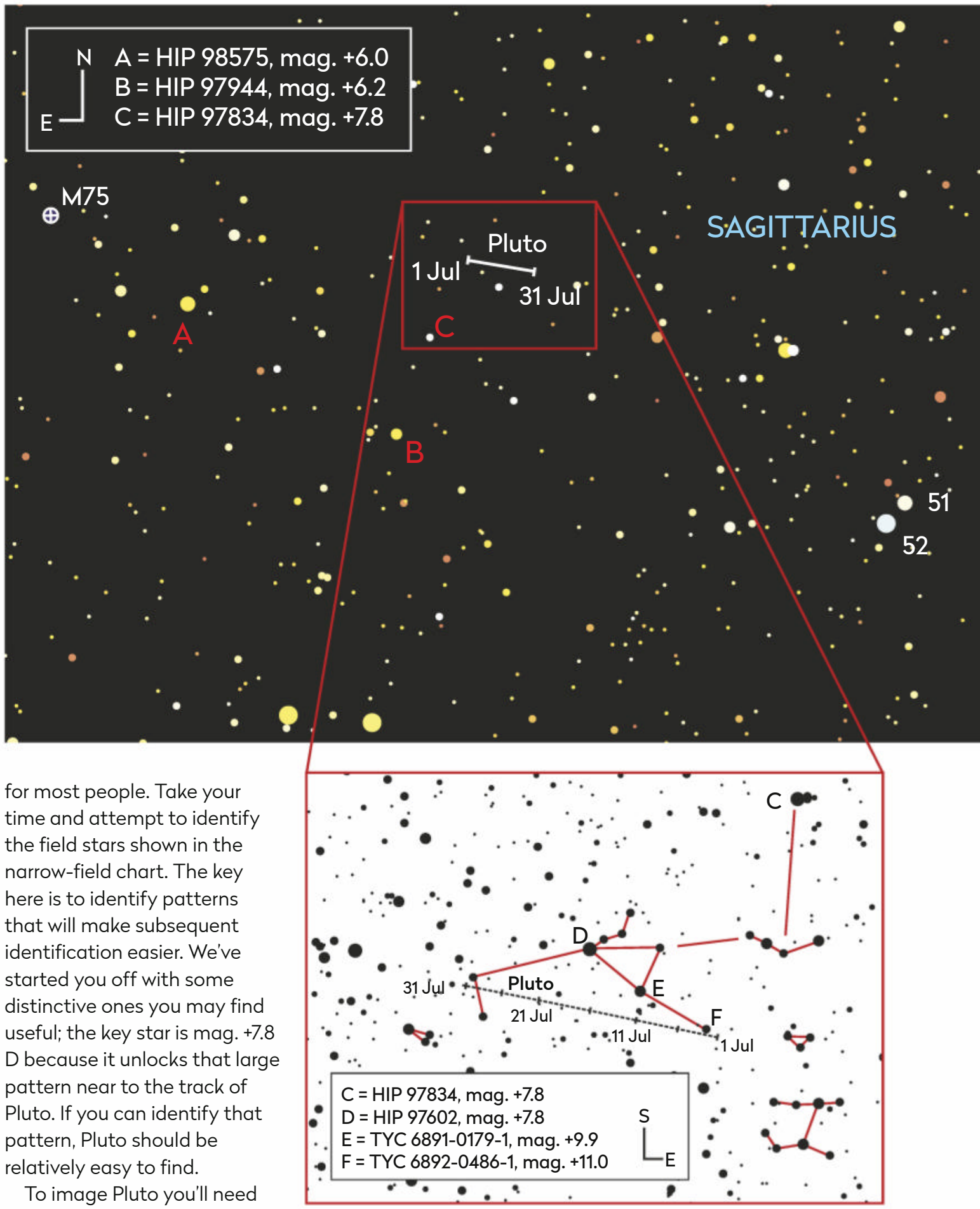
Pluto reaches opposition on 17 July and while technically within the boundary of the faint star-rich constellation of Sagittarius, the Archer, it is now located east of the Milky Way's core region in a relatively barren area of sky just over 3° to the west of the mag. +8.6 globular cluster M75.

M75 is in a good position to be a starting point for finding Pluto. Locate the cluster, then identify the stars to the west and southwest we've marked in our wide-field chart (above) as A, B and C. These are not too faint and shouldn't pose any real issues. Once you've located C, switch to the narrow-field chart (right). This chart is presented upside down to give you a telescopic view. It shows stars down to mag. +14.0, which is likely to be below your telescope's visual range unless you have really dark skies and a large scope over 375mm.

Although there have been claims of visual sightings of Pluto with smaller scopes, its low UK altitude probably means a camera setup is best for most people. Take your time and attempt to identify the field stars shown in the narrow-field chart. The key here is to identify patterns that will make subsequent identification easier. We've started you off with some distinctive ones you may find useful; the key star is mag. +7.8 D because it unlocks that large pattern near to the track of Pluto. If you can identify that pattern, Pluto should be relatively easy to find.

To image Pluto you'll need a tracking mount with a relatively accurate drive and good polar alignment. Dark frames – exposures of the same length as regular imaging shots, but with the lens cap on – are highly recommended. Subtracting these from your regular 'light' frames will help eliminate noise (unwanted artefacts) that could be mistaken for Pluto.

If you're planning to use a standard photographic lens, we'd recommend one with at least a 200mm focal length to provide sufficient image scale. Take photos over the course of several nights, align them and flick between them. Do you see anything faint moving between frames? If so, you might just have caught yourself a dwarf planet.



▲ To find Pluto, use the wide-field chart (above, top) for stars A, B and C; then use the (inverted view) narrow-field chart (above) for D

DEEP-SKY TOUR

Our exploration of objects in Sagittarius, includes the Lagoon and Trifid Nebulae

1 M8

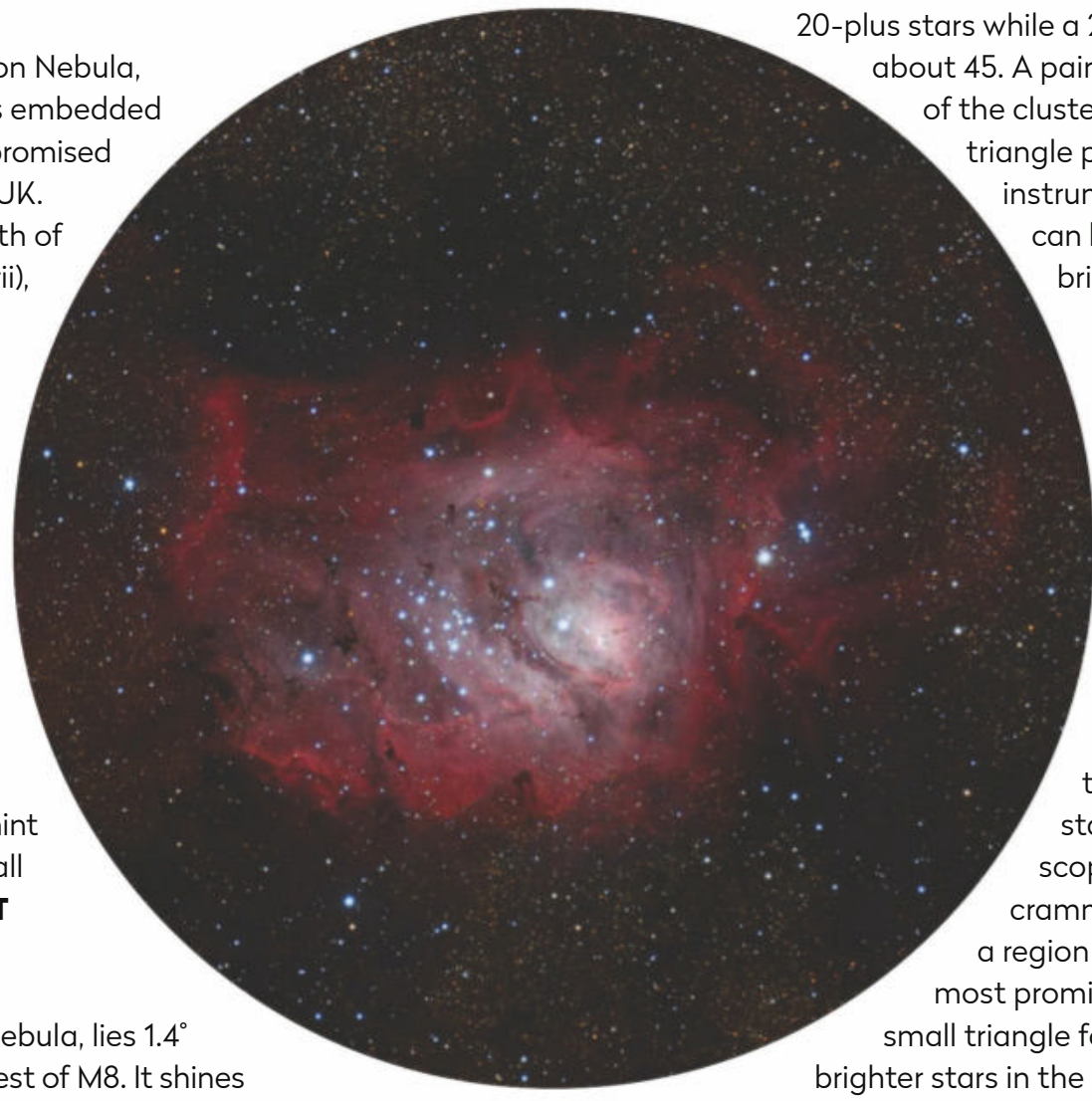
M8, or the Lagoon Nebula, together with its embedded cluster (NGC 6530), is compromised by a low altitude from the UK. M8 is easy to locate, 6° north of Alnasl (Gamma (γ) Sagittarii), the star marking the lip of the Teapot asterism's spout. At mag. +4.6, the Lagoon is visible to the naked eye and an easy target for a 150mm scope. It looks divided – a bright condensed nebula separated from its associated star cluster by a dark lane. A few bright stars can be seen in the nebula's bright part and a hint of nebulosity can be seen all over the cluster. ☐ **SEEN IT**

2 M20

M20, the Trifid Nebula, lies 1.4° north and 0.3° west of M8. It shines with an integrated magnitude of +6.4, appears 13 arcminutes across and is a beautiful object. A small scope shows M20 as a hazy glow, a bright region to the south with a dimmer glow to the north. Three dark lanes cross the brighter component, features which appear distinct through a 250mm scope. The lanes appear to emanate from the nebula's centre, snaking as they head out to its edge. These lanes give the nebula its name, Trifid meaning 'three lobe'. The brighter southern component is a glowing emission nebula that appears pink on long exposure photographs. The northern glow is reflection nebulosity and appears blue in photos. ☐ **SEEN IT**

3 M21

If you're looking at M20, you'll already be in the correct part of the sky to see the open cluster M21. This is a relatively bright open cluster that shines with an integrated magnitude of +5.9. It has a diameter around 15 arcminutes and is located 0.6° northeast of the Trifid Nebula. The edge of this cluster isn't easy to discern, this being a faint, star-rich part of the sky due to the background presence of the Milky Way. A 150mm scope reveals 20-plus stars while a 250mm instrument shows about 45. A pair of stars sits at the centre of the cluster and forms one vertex of a triangle pattern through smaller instruments. A loop of faint stars can be seen to the north of the bright central pair. ☐ **SEEN IT**



▲ The Lagoon Nebula, M8, is a spectacular target, which is easily visible with a small to medium telescope

MARKUS BLAUENSTEINER/CEDIC TEAM/CCDGUIDE.COM, CHART BY PETE LAWRENCE

4 NGC 6546

NGC 6546 is another open cluster. It is fainter than M21, with a listed integrated magnitude of +8.0. It shares a similar apparent diameter of 15 arcminutes, but it's much trickier to identify thanks to the myriad background stars in the area. A 250mm scope confirms it's a cluster, cramming around 30 stars into a region 10 arcminutes across. The most prominent 'feature' visually is a small triangle formed from three slightly brighter stars in the object's centre. Using a wide-field eyepiece, the region southeast of the cluster appears darker than other directions. NGC 6546 is located 1° southeast of M21. ☐ **SEEN IT**

5 Collinder 367

Collinder 367 is another open cluster near M8, which is listed with an integrated magnitude of +6.4 and an apparent diameter of 37 arcminutes. There are lots of stars in this region and it's tricky to know where the background ends and the cluster begins. Collinder 367 can be found by extending the line from M21 through NGC 6546 for a further three-quarters of a degree. Some weak patches of diffuse nebulosity run through the region, listed as IC 1274, IC 1275, IC 4685 and NGC 6559. These are best revealed through long-exposure imaging. Smaller instruments reveal 15 well-defined stars. ☐ **SEEN IT**

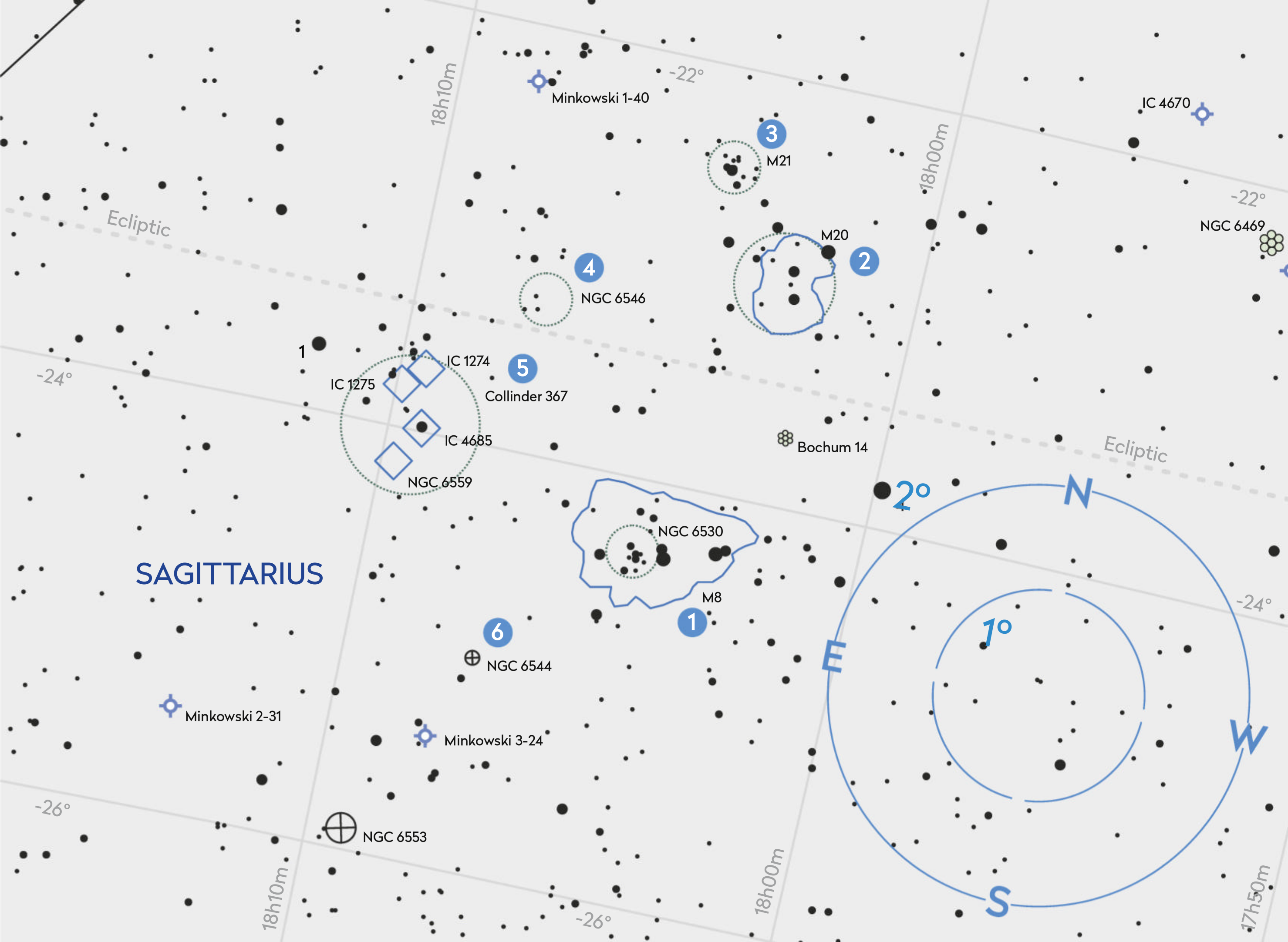
6 NGC 6544

Globular cluster NGC 6544 lies 1° southeast of M8. It has an integrated magnitude of +8.1 and is easy to see with smaller scopes. A 150mm instrument will begin to resolve some of its outer stars and will show a 12th magnitude star just to the west of the cluster's core. It's quite small through a 250mm scope, slightly elongated in a northwest-southeast direction, and it appears around 1.5 arcminutes across. Higher powers show some mottling in the cluster's general appearance and reveal a brightening towards the core. Also, a number of brighter stars give the false impression that the core is off-centre. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.


Minkowski 1-40
18h10m
-22°
IC 4670
3
M21
18h00m
-22°
NGC 6469
Ecliptic
M20
2
4
NGC 6546
1
IC 1274
5
IC 1275
Collinder 367
-24°
IC 4685
Bochum 14
Ecliptic
NGC 6559
NGC 6530
SAGITTARIUS
M8
1
6
NGC 6544
Minkowski 2-31
Minkowski 3-24
-26°
NGC 6553
18h10m
-26°
18h00m
17h50m
2°
N
1°
E
W
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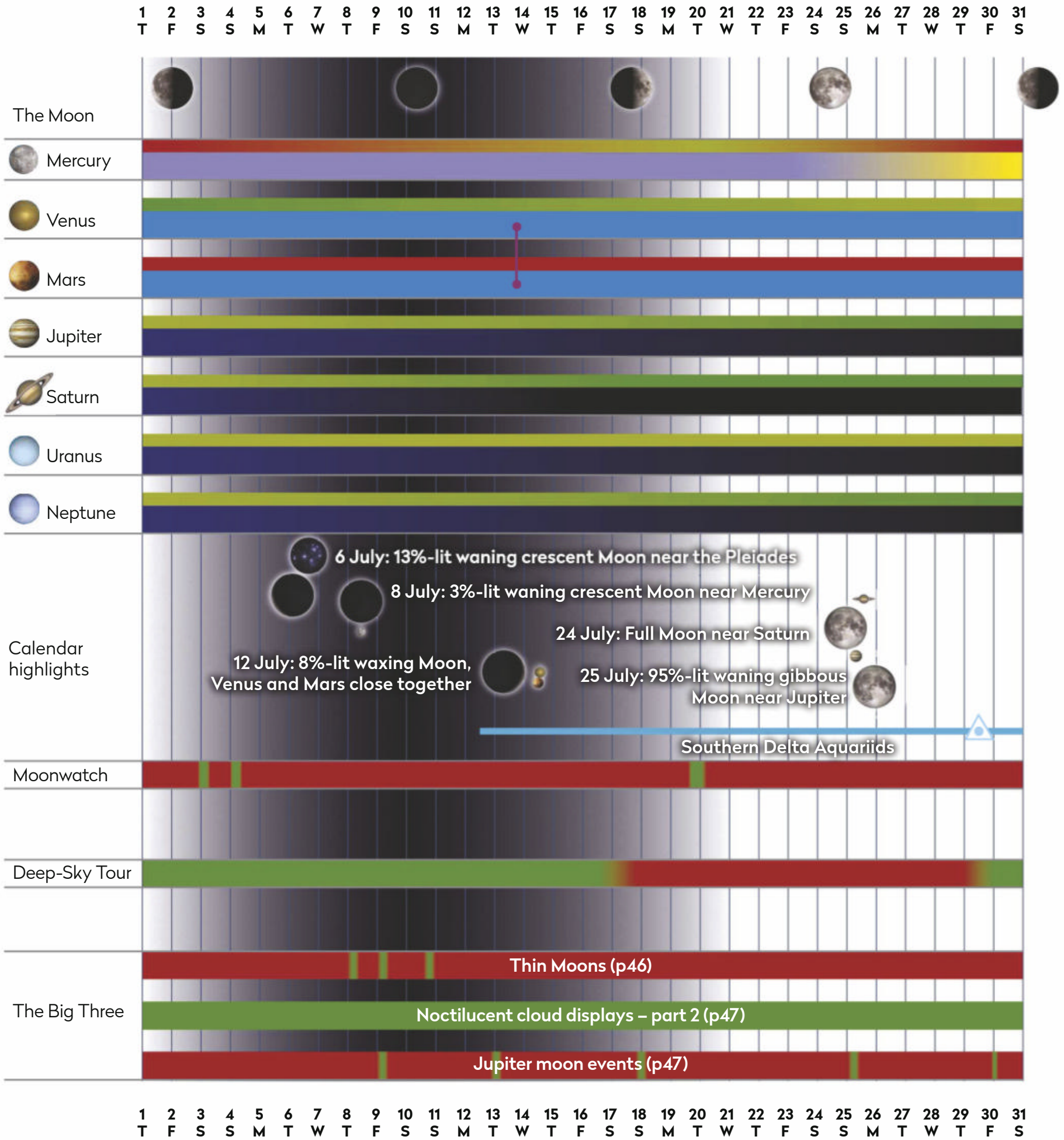
AT A GLANCE

How the Sky Guide events will appear in July



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

BBC Sky at Night MAGAZINE

VIRTUAL EVENT

A star up close: how to observe and image the Sun safely

With Pete Lawrence

ALL PICTURES: PETE LAWRENCE

Observing the Sun is a great opportunity to watch the dynamic nature of a star up close, and there are many ways to see captivating solar detail, revealing a hidden side to the nuclear furnace at our Solar System's centre.

But solar observing also carries a risk of serious damage to health – the Sun's intense brightness can permanently impair eyesight if looked at directly, both with or without a telescope.

However, it is possible to enjoy close-up views of our local star and in this talk, expert solar imager Pete Lawrence will guide you through practical steps to safe solar observing, both with and without optical aids.

He will show the details that can be viewed with everything from simple eclipse glasses to imaging setups with specialist optical filters – features like sunspots, cells and prominences – and how these views can reveal the inner workings of the Sun which are not visible in normal 'white light'.

Pete will also look at how to image the Sun and create a lasting record of its dynamic activity, covering the types of equipment that are most suitable.

As always, you'll be able to submit your questions during the talk, which will be answered live in the second part.

When: Thursday 1 July 2021, 7pm BST
Where: Live on Big Marker
Tickets: £10 per person

Pete Lawrence is a co-presenter on BBC Four's *The Sky at Night*, and writes the monthly Sky Guide in *BBC Sky at Night Magazine*. He has been observing the Sun since 1977.

Book your tickets today at: http://bit.ly/observesunwebinar

Shortened web address above will open *BBC Sky at Night Magazine's* event page on the Big Marker website, where tickets can be purchased.
Full destination URL: https://www.bigmarker.com/immediate-media-co/BBC-Sky-at-Night-Magazine-A-star-up-close-how-to-observe-and-image-the-sun-safely

APOLLO 15

On the 50th anniversary of Apollo 15, **Ezzy Pearson** takes a look back at the Apollo mission that finally placed science front and centre

By the time of Apollo 15, the world was becoming disenamoured with human lunar exploration. The Soviets had managed to both return a soil sample robotically and set down a robotic rover at the tail end of 1970. If they were doing the same work as Apollo, but at a fraction of the cost, why was NASA still sending humans to the Moon?

NASA was already suffering huge cutbacks, leading to the cancellation of the future Apollo 18 mission. With only three missions left, the agency made Apollo 15 the first of their 'J' missions, where scientific yield was the priority.

Bound for the lunar mountain range known as the Apennines, the Apollo 15 astronauts would have to perform complex geology fieldwork, so NASA sent the moonwalkers – commander Dave Scott and lunar module pilot Jim Irwin – on regular field trips as part of their training. Here they learned the skills they would need, especially if they were to find the top item on the geology team's wish list – an anorthosite rock, dating from the earliest era of the Moon's surface. Over dozens of outings the military pilots were transformed into capable field geologists.

The crew launched from Cape Kennedy on 26 July 1971, following a new trajectory which placed them in a parking orbit 166km lower than previous missions. The change was to accommodate a heavier Lunar Module, packed with instruments required for the scientific focus of 'J' missions. The crew set course for the Moon and arrived in orbit three days later, ready to set down near a long canyon known as Hadley Rille. On 30 July, Scott and Irwin crossed ▸

MISSION BRIEF

Launch date: 26 July 1971

Launch location: Launch Complex 39A

Landing location: Hadley–Apennine region

Time on surface: 66 hours, 55 minutes

Distance covered by the Lunar Rover: 27.9km

Duration: 12 days, 7 hours, 11 minutes

Return date: 7 August 1971

Main goals: Explore the Hadley–Apennine region; set up and activate lunar surface scientific experiments; evaluate the new Apollo equipment; conduct lunar observations from orbit

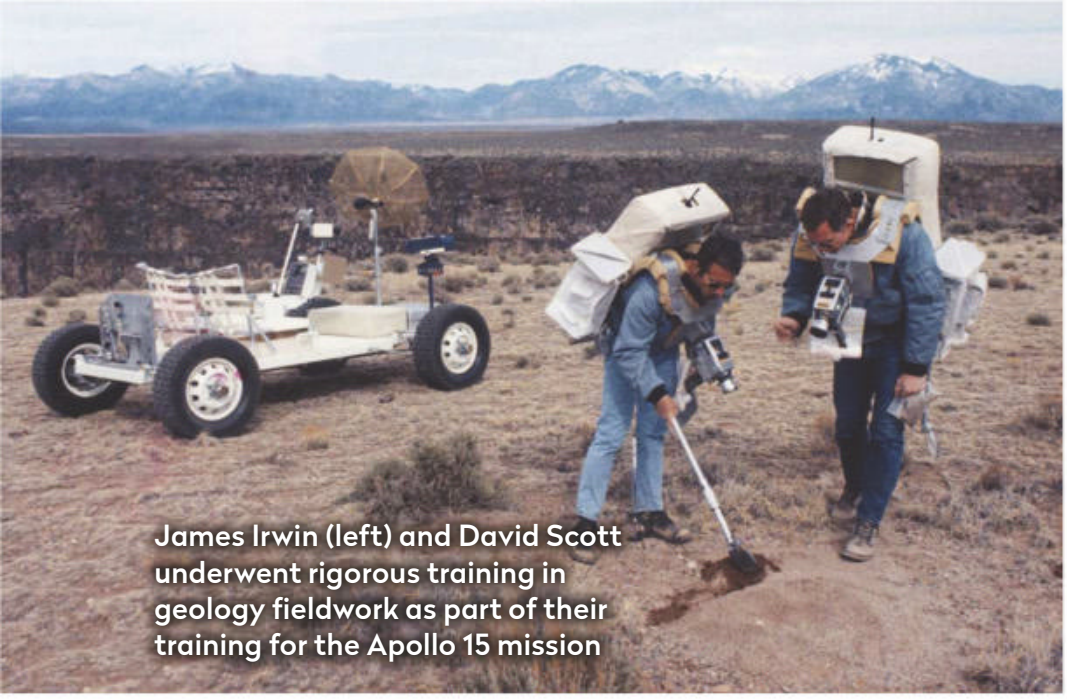
Achievements: first Lunar Rover drive on the lunar surface; first spacewalk in deep space; furthest distance travelled from a Lunar Module on the surface; longest duration on the lunar surface

Lunar Module name: Falcon

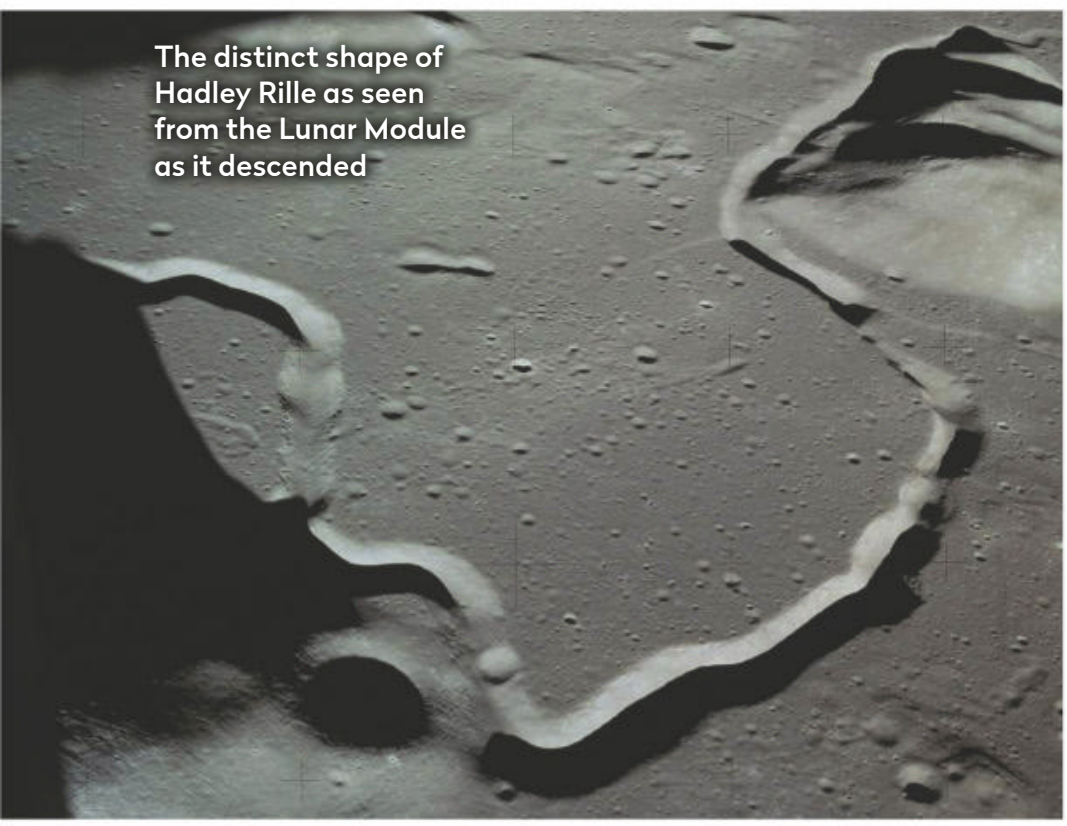
Command Module name: Endeavour

NASA X 7

Hadley Rille was close to the Apollo 15 landing site and it proved to be far less steep than photos from above had initially indicated



James Irwin (left) and David Scott underwent rigorous training in geology fieldwork as part of their training for the Apollo 15 mission



The distinct shape of Hadley Rille as seen from the Lunar Module as it descended

Despite an ignition issue with the second stage of the Saturn V rocket, the Apollo 15 launch on 26 July 1971 was a success

▸ over to the Lunar Module, Falcon, and began to make their descent.

At first things seemed to be going well, until Scott noticed the bright flank of a mountain on his left he hadn't been expecting. A moment later, Mission Control in Houston reported they were almost a kilometre south of where they were meant to be. Luckily, he could make out the dark slash of Hadley Rille cutting through the landscape and used it to guide the Falcon in for a smooth landing.

Taking in the surroundings

Safely landed, it was time for the first item on the agenda – a good night's rest. Apollo 15 would remain on the surface longer than any previous mission and to avoid 'moon-lag', the crew would work and sleep on Earth time, meaning it was time for bed. Before that though, Scott did something any good geologist would do – he began to reconnoitre the area from a high place, namely the Lunar Module's top hatch.

After donning their space suits, Scott conducted the first ever 'stand-up EVA' (extravehicular activity). He surveyed the area, identifying features that had previously only been blurry patches on an orbital image. After half an hour, he offered his colleague the chance to look, but Irwin said no – after days of disorientating weightlessness, he was looking forward to sleeping under gravity again.

The pair woke the next morning and suited up ready for the first of three EVAs. Stepping out onto the lunar surface, they were greeted by the sight of the Apennine mountains glowing gold in the morning Sun. Despite years of preparation and simulations, neither were prepared for how stunning the lunar surface was.

"Oh boy," said Irwin, shortly after walking out onto the surface. "It's beautiful out here! Reminds me of Sun Valley [a ski resort in Idaho]."

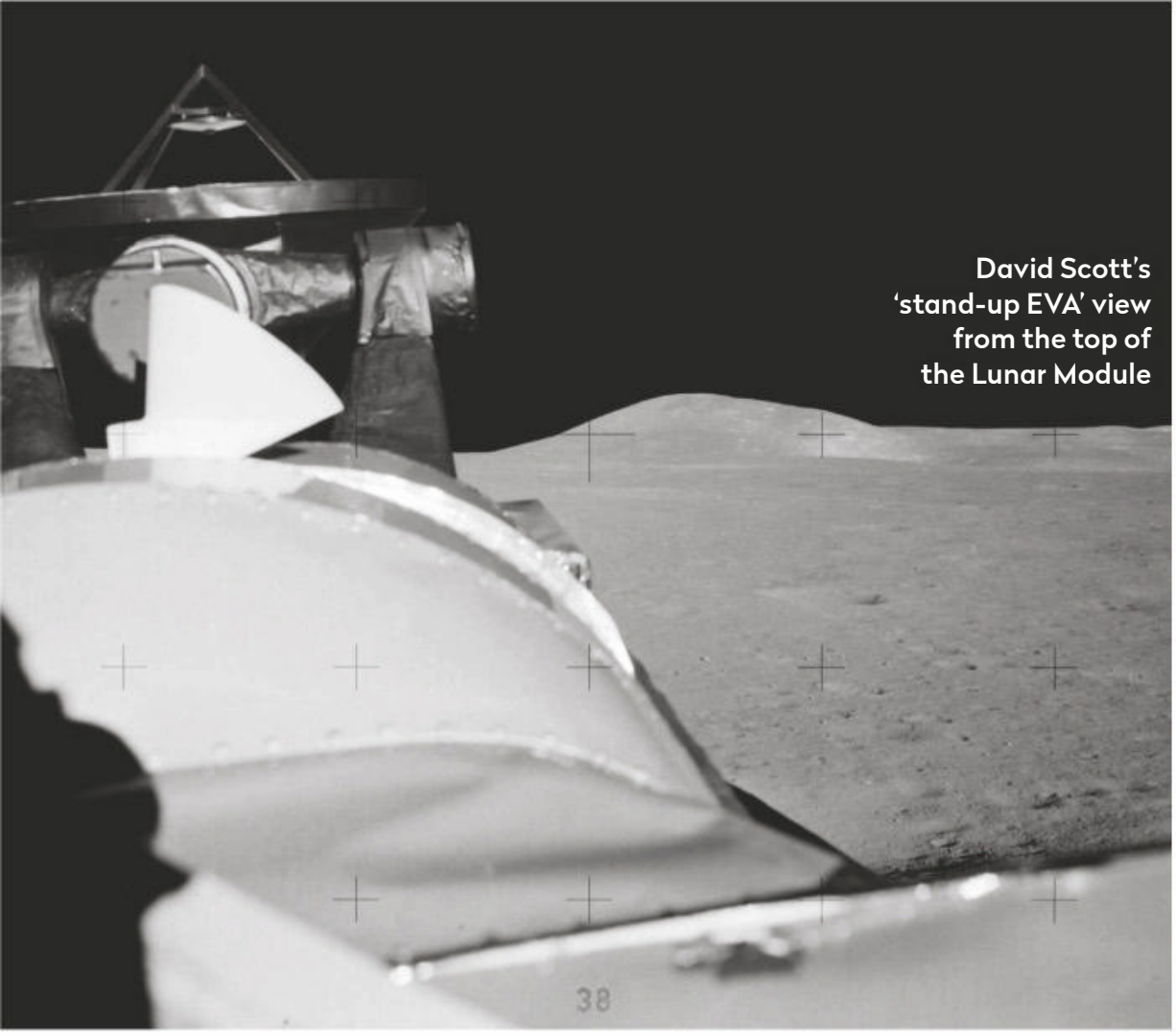
NASA X 10

Meet the astronauts

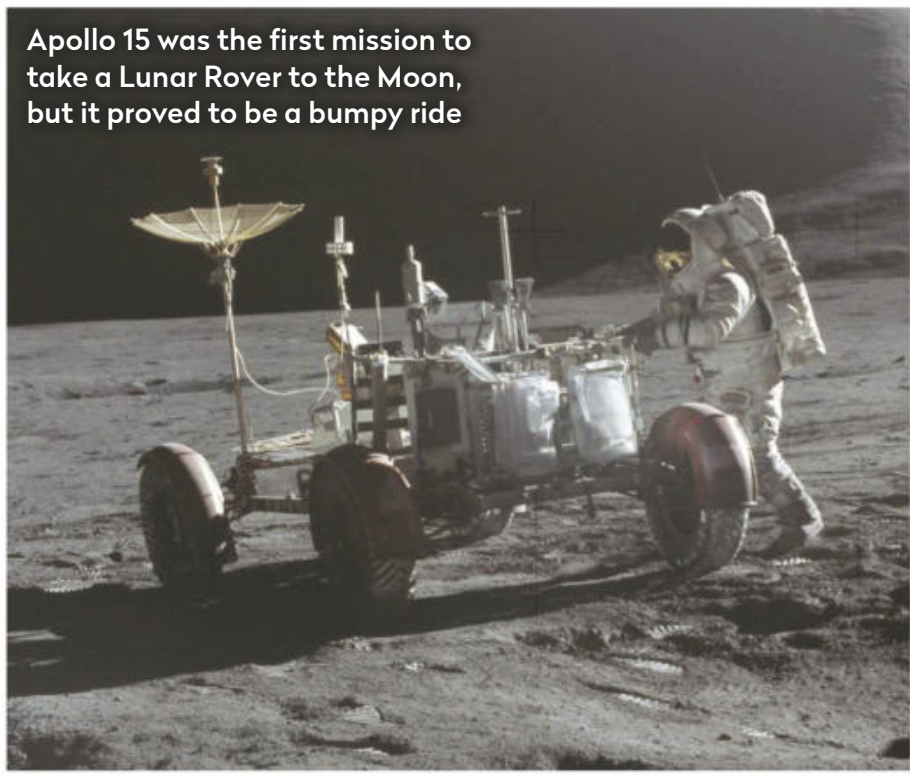
Commander: David Scott
A former Air Force test pilot, Scott joined NASA in 1963. He flew on Gemini 8 alongside Neil Armstrong, and during Apollo 9 he piloted the Command Module while his colleagues took the Lunar Module on a test flight. He later worked on the Apollo–Soyuz project and was director of NASA's Dryden Flight Research Center.

Lunar Module pilot: James Irwin
Before joining NASA in 1966, Irwin was a military test pilot. He left NASA shortly after Apollo 15; he'd found the trip a religious experience and it inspired him to set up the evangelical High Flight Foundation. Under its banner, he mounted expeditions to find the remains of Noah's Ark on Mount Ararat. He died on 8 August 1991 aged 61.

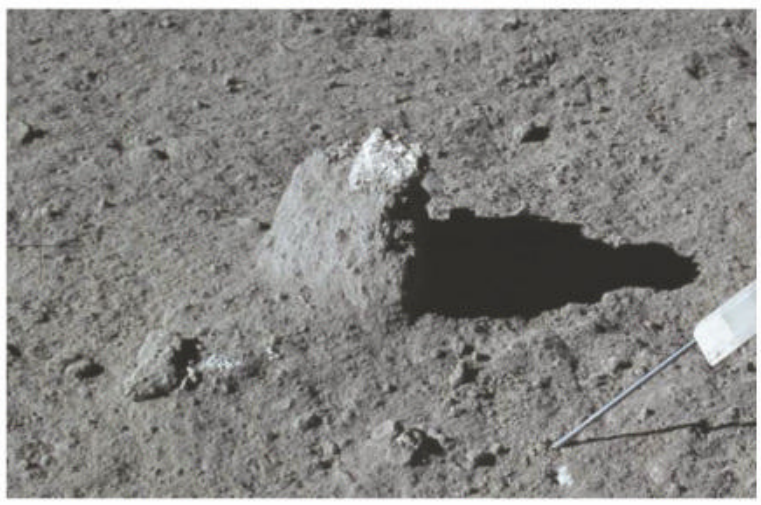
Command Module pilot: Alfred Worden
Previously an Air Force test pilot, Worden joined NASA's fifth astronaut class with Irwin. During Apollo 15, he earned the record for 'most isolated human ever', as his orbit took him a record 3,600km from his colleagues on the surface. After NASA he worked with the Astronaut Scholarship Foundation. He died on 18 March 2020.



David Scott's 'stand-up EVA' view from the top of the Lunar Module



Apollo 15 was the first mission to take a Lunar Rover to the Moon, but it proved to be a bumpy ride



► **Right, top: the Genesis Rock – pictured in situ on the lunar surface – is significant because it formed not long after the Moon itself, some 4 billion years ago**

Right, below: safely back on Earth, the Genesis Rock is stored at NASA's Lunar Sample Laboratory Facility (LSLF) in Houston, Texas

"As I stand out here in the wonders of the unknown at Hadley, I sort of realise there's a fundamental truth to our nature. Man must explore."
– Dave Scott's first words on the Moon

But there wasn't time to stay admiring the view. There was a heavy science workload to get through, which was why their first task was to bring out the latest innovation in planetary exploration – the Lunar Rover.

Apollo 15 would stay longer and go further than any mission before, but even the shorter distances covered by previous moonwalkers had left them exhausted. Predicting this might be the case, NASA had been working on creating a Lunar Roving Vehicle which was finally ready to fly on Apollo 15.

Despite being a sophisticated piece of space hardware, the Lunar Rover looked more like a homemade go-cart. The lower gravity meant it could have a lighter (more flimsy) frame while the seats looked like garden chairs and the wheels were made from mesh wire.

Even travelling at a sedate 10kmph, the wheels would launch into the air after going over the slightest bump – an experience Irwin in the passenger seat likened to riding a bucking bronco. To make matters worse, the front wheels weren't working, meaning Scott could only steer using the rear wheels as he swerved around craters. It was just as well that the Lunar Rover was equipped with a navigation system, so he could fully concentrate on driving.

The pair headed out towards Hadley Rille, before stopping at nearby Elbow Crater to take rock samples. Throughout, Irwin and Scott took pictures and fed back their observations to the geology teams on Earth. These details, along with footage from the Lunar Rover's video feed, would give the scientists vital context needed to fully understand any samples brought back. After six hours on the surface, they returned to the Landing Module for a well-earned meal and a good night's rest.

Landmark discovery

The next morning, the pair started their second EVA with the discovery that the Lunar Rover's steering issue had fixed itself. It handled the drive across the bottom slopes of the Apennine mountains with ease, managing both the angled terrain and the thick dust far more ably than the astronauts themselves did.

"Man, I'd sure hate to have to climb up here," Scott said, after sinking into the thick dust. "You'd never get here without that thing."

It was during this EVA they found an unassuming white rock, which greatly excited Apollo 15's two rookie geologists.

"Guess what we found!" Scott excitedly reported back to Houston. "I think we might [have] ourselves something close to anorthosite, because it's crystaline... what a beaut."

It was just the example of the Moon's early lunar crust the science team had been hoping to find. Later dubbed the 'Genesis Rock', it turned out to have been formed just 300 million years after the Moon and was one of the Apollo programme's greatest finds.►

> "Look at that. We're up on a slope Joe [Allen], and we're looking down into the valley and – that is spectacular!" Dave Scott

▸ But time was pressing on and their oxygen was dwindling as they approached their 'walk back limit'. The lander was now around 4km away and NASA wasn't willing to risk them going any further as they wouldn't have enough oxygen to return on foot if the Lunar Rover failed. With one last stop to deploy the suite of instruments known as the Apollo Lunar Surface Experiment Package (ALSEP), they returned having driven around 12.5km over seven hours.

The view from above

While they were labouring on the surface, Command Module pilot Al Worden was being kept just as busy surveying the lunar landscape from above in the Endeavour Command Module. For the three days he spent on his own, Worden operated science experiments on the spacecraft such as one attempting to sniff out potential gases being given off by the Moon. While passing over the Sun-lit dayside of the Moon, Worden would methodically image its surface until he crossed into the dark of the nightside, allowing him to look out and view the full majesty of the Universe. "What I found was that the number of stars was just so immense," he later said in an interview with the BBC. "In fact, I couldn't pick up individual stars, it was like a sheet of light."

Back on the surface, Scott and Irwin began their third and final EVA two hours behind schedule. But before they could go anywhere, they had to deal with what had become Scott's nemesis – his drill. When using it, the drill's vibrations would shake his hands, while his pressurised gloves fought against his grip, trying to prise his hands open. To make matters worse, the short gloves constantly rubbed against the fingertips of both astronauts, leaving them feeling like their fingers had been beaten with a hammer.

During the second EVA, Scott had painfully driven the drill 3m into the ground to take a deep core sample, only for it to become stuck fast in the dense

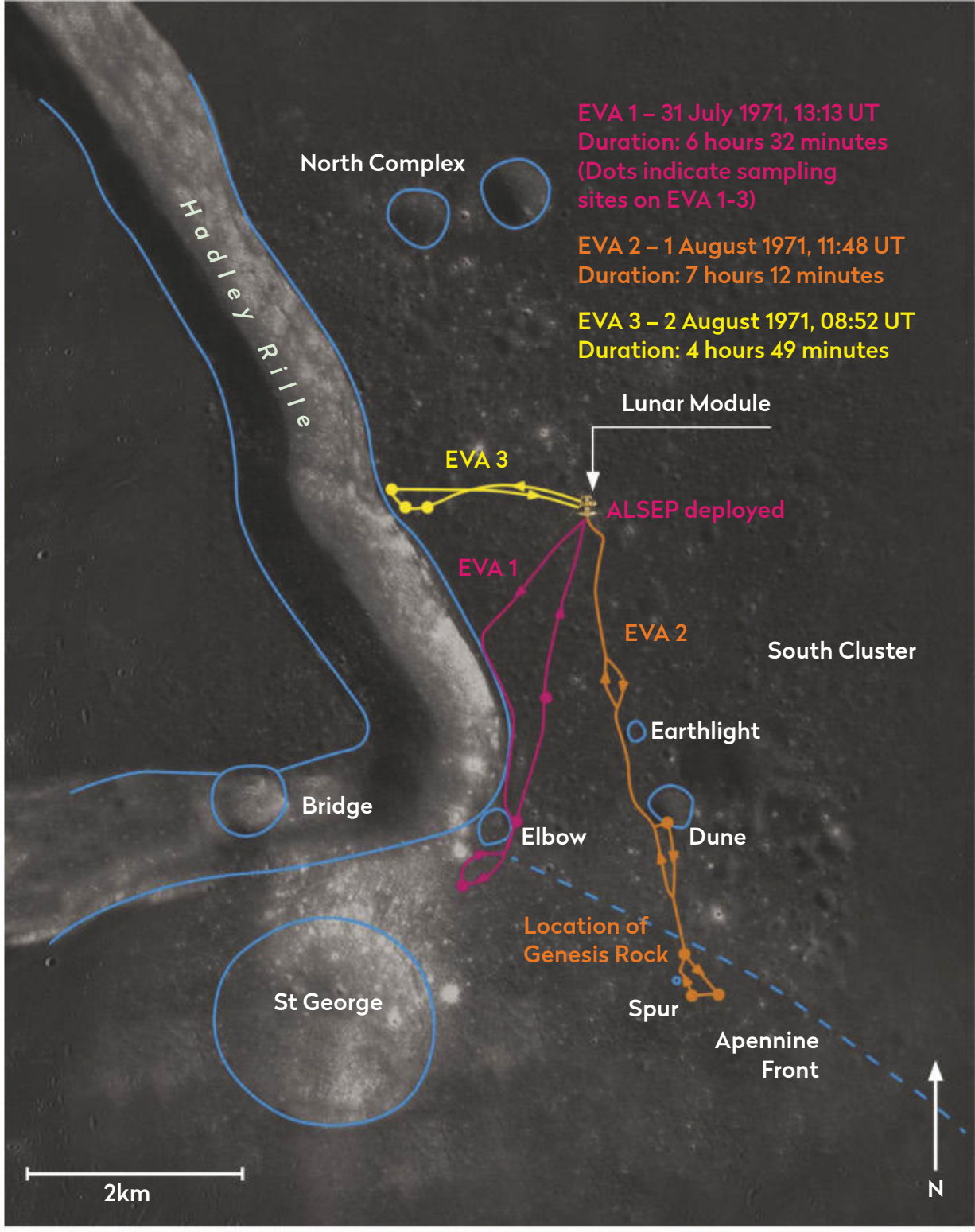
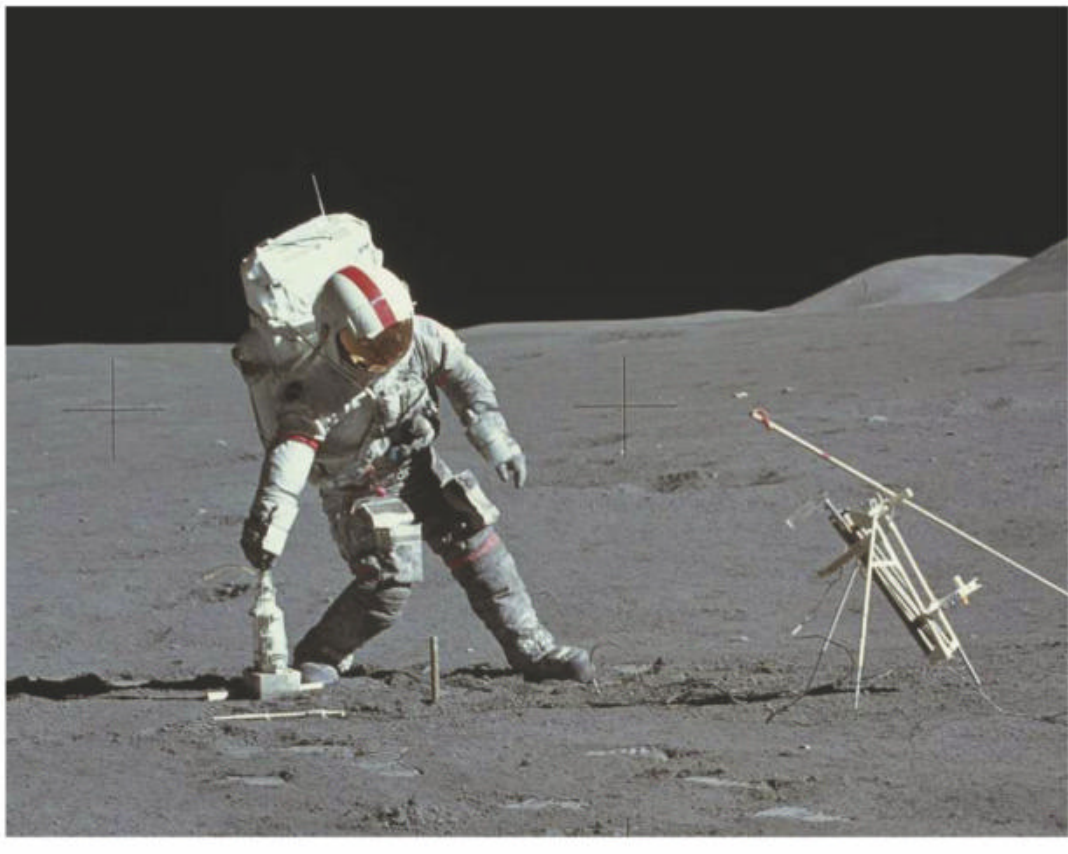


ILLUSTRATION BY PAUL WOOTTON (BASED ON NASA DATA) NASA X 6

▲ Apollo 15's three EVAs (extravehicular activities) by Scott and Irwin covered an impressive distance of 27.9km

▲ The ALSEP (Apollo Lunar Surface Experiments Package) was deployed on the final stop of Apollo 15's first EVA



▲ On the third EVA, Scott battled with a drill while taking a deep core sample; it got stuck in the soil and he needed help retrieving it

MISSION TIMELINE

26 July 13:34*
The crew blast off from Cape Kennedy

26 July 16:56
The Lunar Module detaches from the Command Module, turns around and redocks, ready to travel to the Moon

29 July 20:05
Apollo 15 reaches lunar orbit

30 July 18:13
The Lunar Module departs from the Command Module, heading for the Moon

30 July 22:16
The Lunar Module touches down on the Moon's surface

31 July 00:16
Scott opens the Lunar Module's top hatch and surveys the landing site, closing the hatch 33 minutes later

31 July 13:13
First EVA commences, lasting 6 hours, 32 minutes

1 August 11:48
Second EVA begins, lasting 7 hours, 12 minutes

2 August 8:52
Final EVA begins, lasting 4 hours, 49 minutes

2 August 17:11
The Lunar Module launches from the lunar surface, redocking with the Command Module two hours later

7 August 20:45
Splashdown in the Pacific Ocean

*All times are UT

▲ A hammer and feather were dropped on the Moon to see how quickly they would fall to the surface...

▲ ...and the 'Fallen Astronaut' memorial was set up to honour astronauts and cosmonauts who had died

soil. Now, it took both Scott and Irwin 28 precious minutes to pry the drill back up, using their shoulders to lift the handle.

Final tasks

With their launch time unmovably set just a few hours away, Scott and Irwin headed back out to the edge of the rille on the Lunar Rover. Rather than the sharp drop off they expected from overhead images, the slope gently curved away allowing the moonwalkers to venture beyond the ridge – much to the consternation of those back on the ground.

"Out of sheer curiosity, how far back from the edge of the rille are the two of you standing now," asked mission controller Joe Allen, viewing them from the Lunar Rover's camera. "It looks like the two of you are standing on the edge of a precipice."

After a rushed sample collection, the pair returned to the Lunar Module and hurriedly started packing up, though Scott did find time for two last-minute tasks. First, he pulled a falcon feather out of his suit along with a geology hammer. In a recreation of a famous experiment supposedly done by Galileo, he dropped both of them together to show objects fall with the exact same speed, regardless of weight.

"Nothing like a little science on the Moon," said Scott.

The second task was a more sombre affair – placing a small plaque in memorial to those who had been killed in the effort to transport humanity to the stars, including three Soviet cosmonauts who had died a few weeks before the Apollo 15 launch.

After an arduous mission, Falcon relaunched from the lunar surface and reconnected with Endeavour. With a brief interlude for Worden to perform a spacewalk to recover cameras on the outside of the spacecraft, it was time to set course for home.

Unfortunately, soon after the crew arrived back, they were caught in a major scandal – they'd taken unauthorised postal covers with them to the Moon that they then sold to a stamp dealer. When this was revealed, they were pilloried in the press and NASA banned all three from ever flying again.

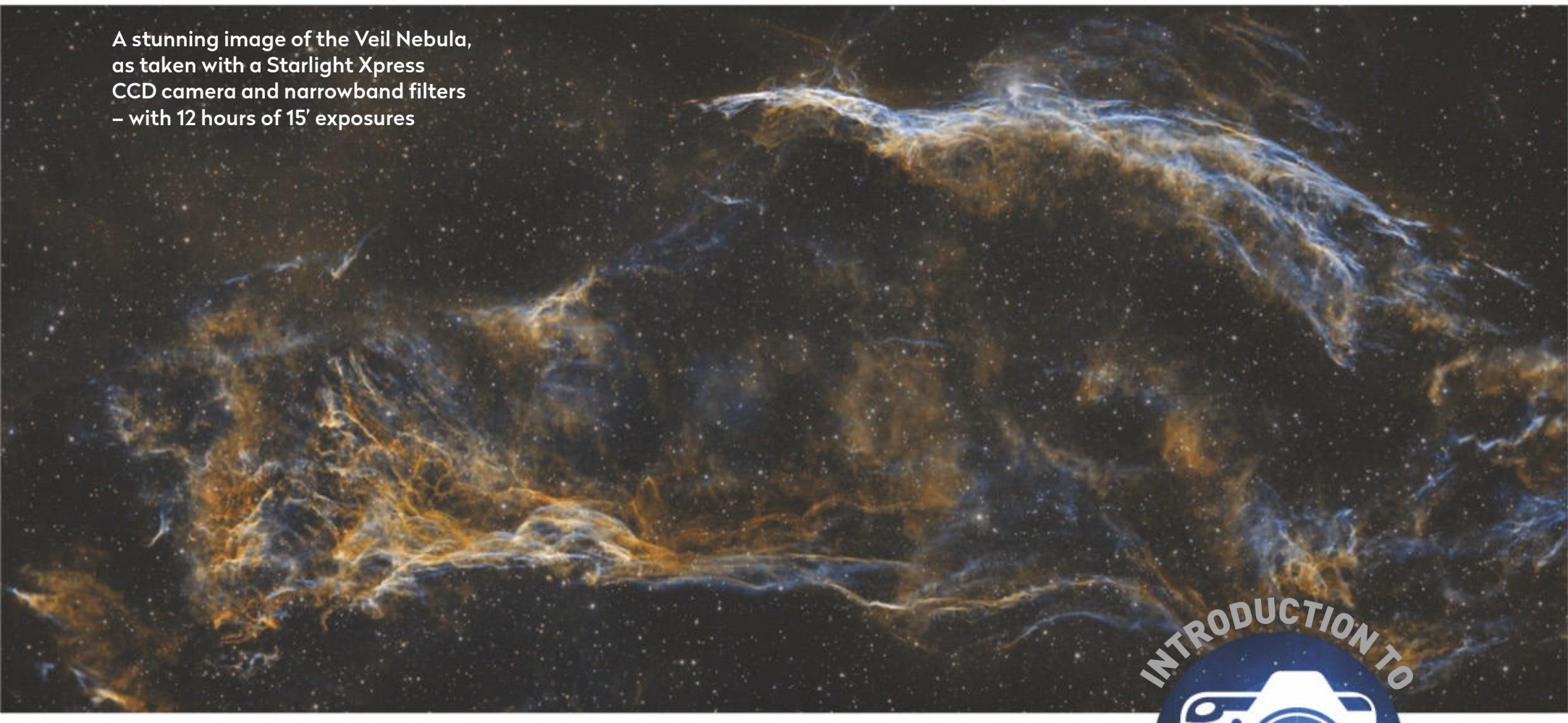
Despite this sour note, Apollo 15's real legacy was the wealth of scientific insight it produced. The Genesis Rock gave a window into the Moon's earliest eras, while the hard-won deep core sample was used to reveal the past 500 million years of lunar history. In just three days, two astronauts had proved just what could be achieved by sending humans to the surface of the Moon.

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

▲ The crew splashed down on 7 August 1971 with one malfunctioned parachute trailing above them

▲ Each astronaut received NASA's Distinguished Service Medal, but controversy was soon to follow

With the right setup you can capture beautiful images of the deep sky, as this image of the Orion Nebula – taken with an SBIG CCD camera and a TEC 140ED refractor – demonstrates



A stunning image of the Veil Nebula, as taken with a Starlight Xpress CCD camera and narrowband filters – with 12 hours of 15' exposures

INTRODUCTION TO ASTROPHOTOGRAPHY

Capturing the DEEP SKY

In the final instalment of our imaging series **Charlotte Daniels** looks at how to take great images of galaxies and nebulae

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

There are many branches of astrophotography to explore, from capturing the Moon's craters, to wide-field starscapes of our Milky Way. But perhaps the most demanding images to take are those of deep-sky objects. Deep-sky photography includes images of nebulae, galaxies and star clusters, and whether you're a seasoned daytime photographer or a complete beginner, doing justice to these faint fuzzy targets takes time and patience.

However, practice makes perfect and deep-sky photography is extremely rewarding right from the word go: you can image a target and unlock details that are simply invisible to visual astronomers.

With a bit of practice, amateur astrophotographers can capture images of the deep sky that are reminiscent of the Hubble Space Telescope. If you're curious about deep-sky imaging and want to know what you need (versus what you may want to buy later once you've honed your skills), over the following pages we run through some key elements. ▸

ROBERT SCHULZ/CCDGUIDE.COM, CHRIS GRIMMER

Deep-sky equipment

The cameras and telescopes that best reveal the details of deep space

Deep-sky imaging makes great demands on your kit because you need to achieve long exposures to capture the maximum amount of detail in your images. The good news is there are many setup options for beginners. The type of camera you use is particularly important so we'll cover that first here, but there are other things to consider, so we'll also look at telescopes and then move on to accessories – including mounts, autoguiding systems and filters.

Cameras

You can start deep-sky imaging with a DSLR camera. This meets the basic needs, as most have a Bulb mode to run long exposures, adjustable light sensitivity (ISO) and are relatively easy to operate. But perhaps a DSLR's great advantage for a beginner is that it's a relatively uncomplicated setup. Indeed, there are some deep-sky objects you can image using a DSLR and a zoom lens, such as the Orion Nebula and the Heart and Soul Nebulae.

You need a sturdy mount (which we'll discuss on pages 70 and 71), plus a remote shutter release such as an intervalometer. This will allow you to set the number of exposures to be captured and the exposure length, and it will also give you the means to start an imaging run without touching the DSLR.

DSLRs can capture impressive deep-sky images, but the sensors don't perform well on exposures over five minutes; for longer exposure times, CMOS and CCD cameras offer lower noise (unwanted artefacts).

CMOS and CCD cameras are similar to operate. These are dedicated astrophotography cameras, and don't look like a point-and-shoot camera – they're more like specially adapted industrial cameras. They come in either colour or monochrome versions (the latter requires the purchase of colour filters). What sets them apart from a DSLR is the sensor. The CCD performs better at longer exposures than the CMOS, so to gain the best results expect to run a CCD with exposure times between 10 and 20 minutes.

CMOS and CCD deep-sky cameras are 'passive-cooled' or 'active-cooled', which helps to reduce noise. Passive cooling uses fans to prevent the sensor from overheating and introducing noise, while active cooling combines fans and a Peltier system to maintain a fixed temperature.

A CMOS- or CCD-based setup is more complicated than a DSLR because you need a laptop and software to control the camera and see the images it's taking, which also means access to mains power or a healthy battery is required. As we'll discuss, these cameras also bring with them the need for other accessories such as autoguiding systems.

Telescopes

When you image the deep sky with a telescope, it takes the place of a large lens for your camera. But, unlike visual astronomy, the telescope aperture won't

▼ Find regular reviews of the main types of deep-sky cameras in our 'First Light' section:

1: DSLR camera – a Canon EOS R6 camera, as reviewed in this issue, page 86

2: CMOS camera – an Altair Hypercam 115M monochrome CMOS with thermoelectric cooling (TEC), as reviewed in the June 2021 issue

3: CCD camera – a Starlight Xpress Trius Pro 694, as reviewed in the April 2020 issue

The Andromeda Galaxy is a good starter deep-sky object to capture – a large, bright spiral galaxy, it's the nearest major one to our Milky Way

How to image galaxies

The Andromeda Galaxy makes a great target for a first-time capture

The Andromeda Galaxy, M31, is a great beginner's deep-sky object target because it's easy to find and can be imaged with a DSLR and lens. The equipment needed to capture an image like this comprises a DSLR, a Go-To tracking mount and an intervalometer.

Regardless of the target, every deep-sky imaging session should start with polar aligning. By finding Polaris and positioning it in your mount's polarscope, you calibrate the mount so that it can track the stars accurately. You should then perform a three-star alignment with the mount – this helps its Go-To function find targets reliably.

Whether imaging galaxies or nebulae, achieving sharp focus is crucial. With either target it's the same method: focus on a bright star, such as Vega (Alpha (α) Lyrae), before finding your target.

After locating the galaxy, try out different ISO levels and exposures. As the Andromeda Galaxy has a bright galactic core, select an exposure time that doesn't 'blow out' the centre of your image. (If the core is overexposed, you'll lose detail from the inner dust lanes when it comes to processing the image.) Try 90 minutes of one-minute exposures at ISO 800.

You can combine shorter and longer exposures, however, and his can be done via the stacking process in Photoshop or DeepSkyStacker. In DSS, you can separate different exposure lengths into 'groups' and stack them. In Photoshop, you stack the frames for each exposure separately to end up with a TIFF file for each. After processing the TIFFs separately, you layer one image on top of the other and blend with the 'Hide All' and 'Reveal All' masks.

A remote shutter release helps to capture images of the deep sky, as you can start an imaging run without touching the camera

limit detail – the camera allows us to capture small features even with a small telescope. However, a telescope's focal length versus its aperture is key as this determines the focal ratio, or f/ number. The smaller the f/ number, the greater the telescope's light-gathering capability.

All telescopes types can be used for astrophotography, but Cassegrains are best kept for planetary imaging. Reflectors and refractors are the preferred choices on the deep sky – refractors offer the best optics in a small and light body, but are generally more expensive. Reflectors come in cheaper, but at the cost of size and weight. Some reflectors also have focusing issues once a camera is attached, which require the mirror position to be adjusted.

Field curvature can be an issue with both types of telescope, but this is easily corrected with a field-flattener. Flatteners are one of the more expensive accessories and require precise positioning to work at their best.

For those intending to invest in a telescope and CCD camera, the Astronomy Tools CCD Suitability Calculator (**https://astronomy.tools/calculators/ccd_suitability**) helps to determine how two models will perform together. This takes the focal length of the scope and combines it with the pixel size of the CCD to assess its potential for deep-sky imaging. ▸

@THESHED_PHOTOSTUDIO, X 3, CHARLOTTE DANIELS, PETE LAWRENCE

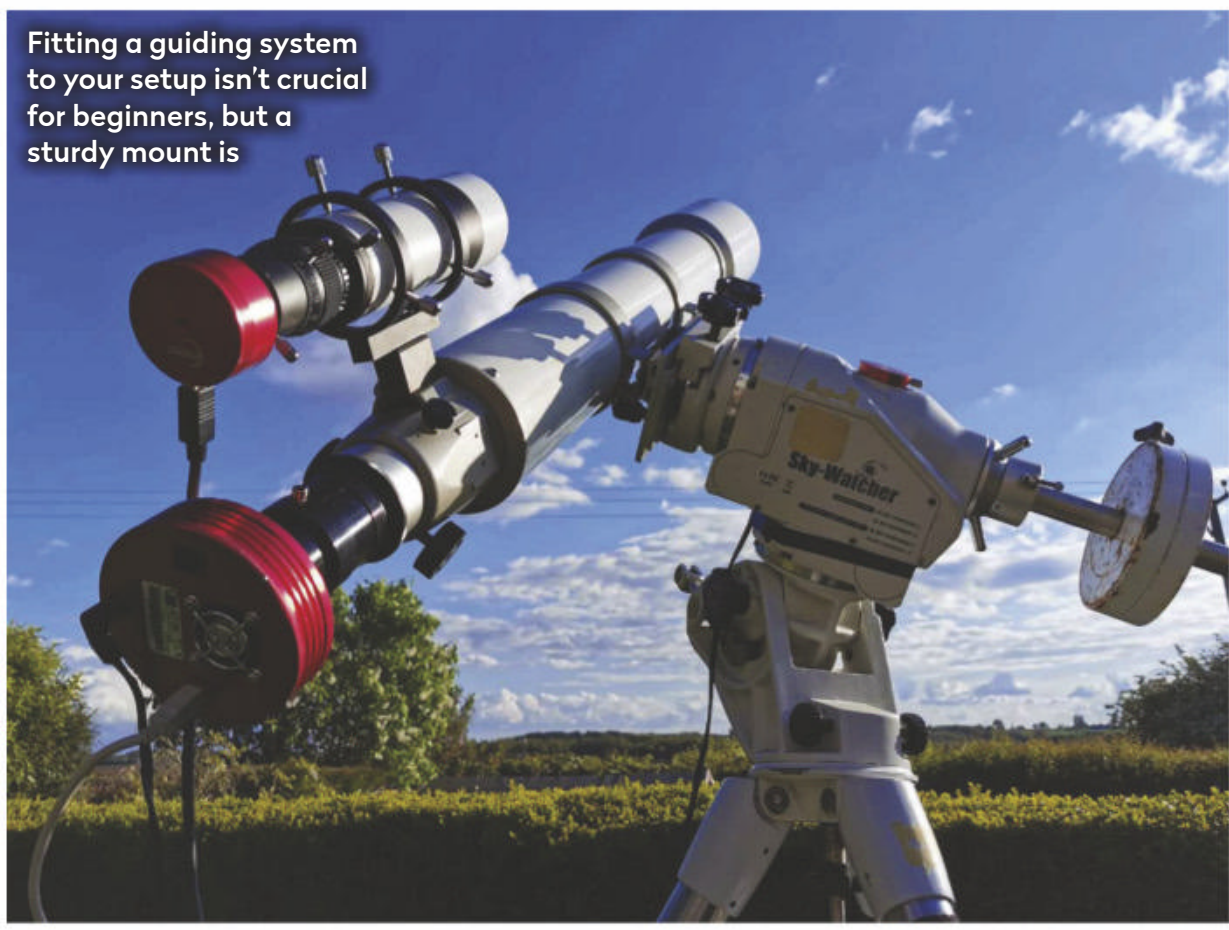
Your deep-sky setup

Your mount is key, but also consider filters and the processing stage

The first thing to ensure for deep-sky imaging equipment is that you have a sturdy mount. For astrophotography this is an essential bit of kit because the maximum exposure length depends on it, and it will protect your imaging equipment and help locate your target if it's a Go-To mount.

For deep-sky imaging you need an equatorial mount (rather than an altaz mount), in addition to motorised axes (or the declination axis at a minimum) that will allow it to 'track' the apparent movement of the night sky, which is known as 'sidereal tracking'. Tracking accuracy is paramount as this is what creates pin-sharp stars; while this is largely due to how well the mount is polar aligned, it's also down to the motor's efficiency.

The mount's payload is important too, because this can also affect tracking. You will find that imaging payload requirements are different from visual ones because astro imaging requires more precision to stay on target. The payload listed in the mount's specifications is typically for visual purposes; halve that figure for imaging.



Fitting a guiding system to your setup isn't crucial for beginners, but a sturdy mount is

Guiding

As beginner deep-sky imagers develop their skill and confidence, many opt to add guiding software to their setups. This connects with the mount to make tracking corrections: a guide camera replaces the finderscope and focuses on multiple 'guide stars' as reference points. This information, fed through the guiding software on a laptop, ensures the mount stays on target and allows for increased exposure times.

Guiding makes a radical difference to images because: a) the increased image exposure times enhance detail, and b) most guiding software has a dithering function. Image dithering reduces 'walking noise', which is an unwanted artefact that comes from stacking image files. But, when you're starting out, one thing to remember is that guiding can complicate things – it's not an essential step for beginners, and it can be worth parking until you're more confident with the camera and mount.

Focal reducers & filters

Depending on the telescope's focal length, focal reducers can come in handy. These reduce the focal length of your telescope by a factor of between 0.5 and 0.8, depending on the model. This allows those with long focal-length telescopes to access more deep-sky targets, as it creates a wider field of view.

Deep-sky astrophotographers also end up investing in narrowband or light pollution filters. Light pollution filters prevent artificial light from reaching the camera sensor, while narrowband filters capture wavelengths emitted from nebulae – including Hydrogen-alpha (Ha), Oxygen (OIII) and Sulphur (SII) – and cut out most other electromagnetic waves. Narrowband filters enhance contrast and details in a deep-sky image. These filters are available for most types of camera – not just CCDs. Two-inch filters can be installed between the telescope eyepiece barrel and camera adaptor, plus there are also clip-in options for DSLRs. Some astro imagers also use a filter wheel if they are using several filters in one night. These are designed to make the transition from one filter to another easier and it means you don't have to detach the camera.

Processing

Those new to astrophotography may think that a processed deep-sky image is artificial or 'faked', because it looks so different to the image of the same object on the back of the camera. However, the processing stage is arguably as important as the capture stage – it is how you draw out the detail that cannot be seen. As deep-sky objects are shot in RAW format, no colour corrections, exposure compensation or noise reduction is done in the camera – it's all done at the processing stage. Instead of seeing processing as 'faking' a deep-sky image, it's better to see it as unlocking the data suppressed in the RAW files.

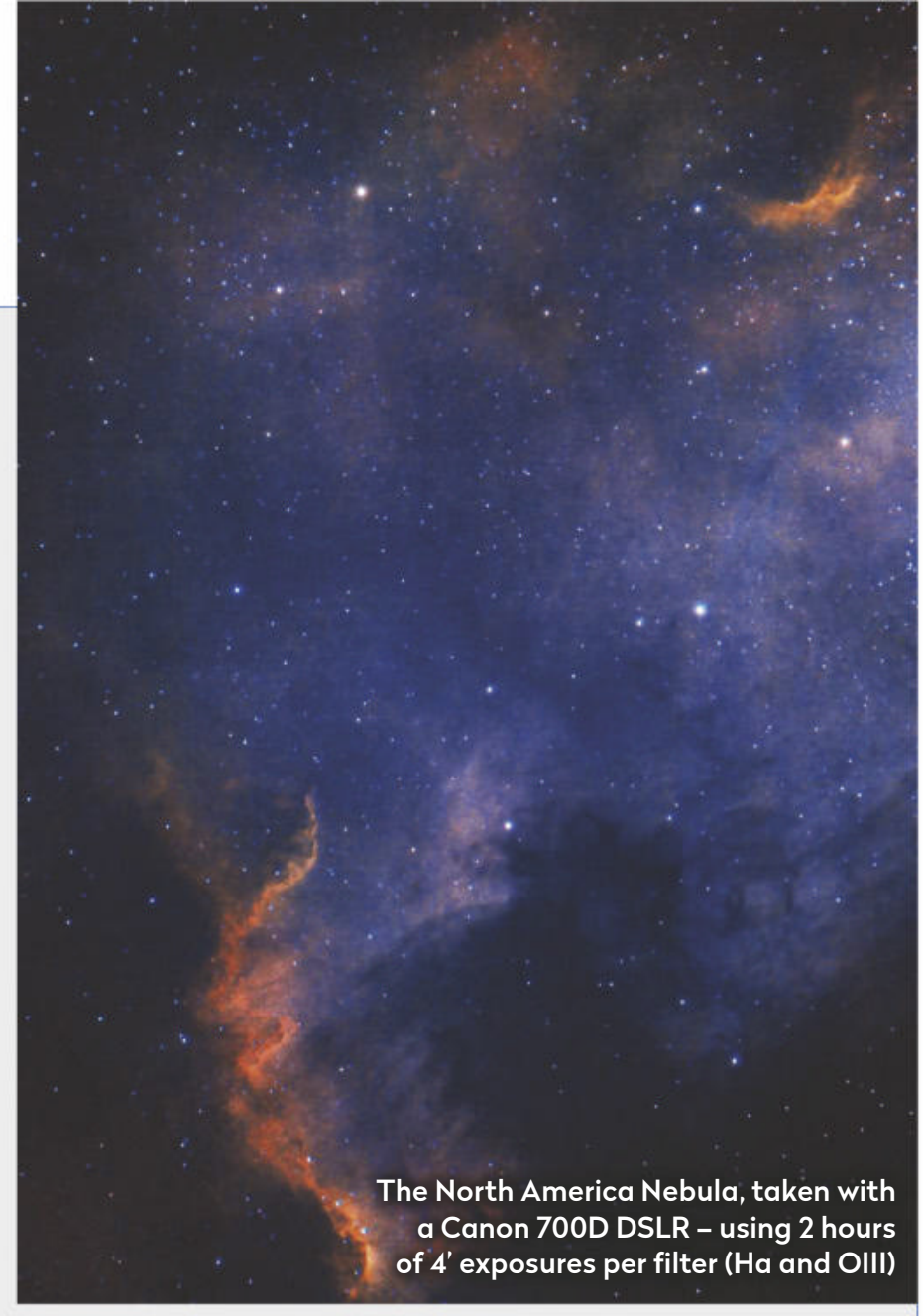
Processing a deep-sky object involves three main stages: image registration, image stacking and a final image process, all done using image-editing software.

▲ A good light pollution filter (top) prevents artificial light reaching the camera sensor, while a narrowband filter (above) enhances contrast and details

PETE LAWRENCE, WIDESCREEN-CENTRE, 365 ASTRONOMY, CHARLOTTE DANIELS, CHRIS GRIMMER X 2

How to image nebulae

Use filters and processing to bring out subtle features in faint clouds



The North America Nebula, taken with a Canon 700D DSLR – using 2 hours of 4' exposures per filter (Ha and OIII)

This is another big, bright deep-sky object that's ideal for beginners. A part of it, known as the Cygnus Wall (see image, right), shows up even in 10–20 second exposures with a high ISO setting, helping you know when you've found the target and how to position it for the rest of the imaging run.

To capture the image on the right, we used a modified DSLR with a clip-in Hydrogen-alpha (Ha) and Oxygen (OIII) narrowband filter added for more detail. If you're shooting this object with an unmodified DSLR, the final image would look mostly red, because the camera would not be sensitive to subtle OIII emissions from the nebulae. Instead, it would just capture some of the Hydrogen. The OIII data we've gathered from the filter is blue in our final image.

We also used guiding for this astrophoto, which allowed us to run four-minute exposures. Without guiding, we would have been limited to about two minutes before the mount started to drift and blur the detail. In the end, we shot a total of two hours of Ha and two hours of OIII for the final image.

The way we processed the North America Nebula image was different to Andromeda, because of the narrowband filters. We stacked and processed each filter separately in DSS, and set the resulting TIFF files to monochrome in Photoshop. We then performed a histogram stretch on each to get as much detail as possible, before combining our Ha data with the Red colour channel and the OIII data with the Blue colour channel. The Green channel was then set to 50 per cent Ha and 50 per cent OIII. The result is this colour image that benefits from all the extra details our narrowband filters have captured.

▲ Revealing the invisible: a RAW frame (left) straight from the camera and a final processed image (right) of the Elephant's Trunk Nebula, show how crucial processing is to unlocking the data held in deep sky captures

DeepSkyStacker and Sequator are used for registering and stacking RAW deep-sky images, while Photoshop, GIMP and PixInsight are used for the final stage.

Also important are the 'calibration frames' that are added during the stacking process. Learning to take good calibration frames will make a difference to your final image: they will reduce unwanted noise, vignetting (reduction in image brightness at the edges of the field of view) and sensor artefacts like motes of dust and dead pixels from a stack of images, which then allows for more scope when processing.

The three main types of calibration frame are darks, flats and biases. Darks and biases reduce electronic and sensor noise, while flats reduce vignetting. Both DSS and Sequator have sections to add these files. It's simple to take both types.

Dark frames are taken at the same ambient temperature, exposure and ISO as your image frames. To get them, pop your lens cap on at the start or end of your imaging run and fire off up to 30 exposures. Bias frames don't require a lens on the camera, but they need the same ISO as your image frames. Keep the camera cap on a DSLR, set the exposure to the fastest exposure time and fire off the bias frames.

Flat frames need to be taken at the same ISO, aperture and focal point as the image frames – so don't nudge the scope or lens after your imaging session. You'll need a white screen – such as a blank piece of A4 – that covers your scope or lens's field of view. The exposure time for a flat file varies depending on if you're using a DSLR, CMOS or CCD camera.

The two contrasting images of the Elephant's Trunk Nebula (above, left) show why processing is so important; by stacking, adding calibration frames and using processing software the initial RAW camera image is transformed into a celestial marvel.

EXPLAINER

The legacy of NASA's Space Shuttles

A decade after the final flight, Melissa Brobby looks back at the Space Shuttle era

This month marks the 10th anniversary of NASA's last Space Shuttle flight: on 21 July 2011 the landing of Shuttle Atlantis bought three decades of the Space Shuttle programme to a close after 135 missions. The Space Shuttles may be permanently grounded, but many historic achievements were made possible by their existence.

When Space Shuttle Columbia lifted off in 1981, piloted by Apollo astronaut John Young and rookie Bob Crippen, it signalled the start of NASA's Space Shuttle programme and the spacecraft became a regular presence in space, launching and repairing satellites while in orbit. Many famous firsts were achieved thanks to the ambitious Shuttle programme, including the launch of the first American woman in space, Sally Ride (in 1983); NASA's first female Shuttle pilot and Commander, Eileen Collins (in 1995); and the first Black American man and woman to fly to space, Guion Bluford (in 1983) and Mae Jemison (in 1992). In 1984, it also saw the first untethered spacewalk, where the Manned Maneuvering Unit (MMU), a propulsion unit, was tested to allow astronauts to move about independently and travel further from the Shuttle.

A significant Space Shuttle mission was the deployment of the Hubble Space Telescope, carried onboard Discovery in 1990. When it was discovered that the telescope had a flawed primary mirror, a further five Shuttle missions took place between 1993 and 2009 to successfully service it; these installed new equipment to correct the flaw and fixed the telescope's stabilising gyros, saving Hubble and keeping it operational.

On a mission

The Space Shuttle was designed to be a low-cost, reusable low-Earth orbital spacecraft. Its durability was down to its unique design; launching facing upwards like a rocket, and returning to Earth like a glider. The Shuttle was able to carry more astronauts and large payloads into orbit, such as satellites and planetary probes, and act as a place to conduct advanced scientific research. Indeed, one of the Space Shuttle's most important tasks was the construction of the International Space Station (ISS), which took 13 years and plenty of Shuttle flights.

▲ The launch of Atlantis on 8 July 2011 was the final chapter of the Space Shuttle era, which had lasted for 31 years

NASA X 3, NASA/BILL INGALLS X 3, CHRIS BRAMLEY

However, the desire for frequent launches resulted in an overstretched workforce and dangerous instances where heat-resistant tiles came away during launch, a main engine failed at the edge of space, and solid-rocket boosters showed signs of hot gas leaking through sealed joints.

Tragedy would strike the Space Shuttle programme twice. In 1986, Challenger exploded 73 seconds into flight killing the entire crew, which included Christa McAuliffe who was to be the first teacher in space. The blame was placed on the failure of a joint in the solid-

rocket boosters and a lax safety culture at NASA. Then in February 2003, Columbia broke up on re-entry, killing all seven crew members. The cause was later discovered to be a chunk of foam that had fallen from the external tank during launch, striking and crippling the heat-resistant tiles. This caused the Shuttle to break up on re-entry, killing all seven crew members. These accidents made it more apparent that the Space Shuttle had major safety problems, and in 2004 President George W Bush announced the retirement of the Shuttle programme once the ISS was completed.

▲ Above left: the Space Shuttle Discovery deploys the Hubble Space Telescope, in April 1990, at a height of 614km above Earth

Above right: Sally Ride, the first American woman in space, is pictured on the flight deck of Space Shuttle Challenger in 1983

The Space Shuttle's legacy

Despite this, the concept of the Space Shuttle led the way for other low-Earth orbit launchers to be developed. One of these was SpaceX's Falcon 9, a two-stage rocket with a reusable first stage that re-enters the atmosphere and lands vertically on a drone ship. But SpaceX is not the only player in the low-Earth orbit spaceflight game; Blue Origin's New Shepard is a reusable launch vehicle with vertical take-off and landing that will serve as a commercial system for suborbital space tourism. And there is also Virgin Galactic, with a reusable suborbital spacecraft that is currently in development for tourism, opening up the possibility for anyone to experience seeing Earth from space – if you have the funds, that is.

Outside the US, it is believed that China launched its own reusable space plane in September 2020, and possibly has both crewed and uncrewed projects in development. Also, India's Avatar, a reusable orbital spaceplane, is being developed to launch military and commercial satellites and is set to be completed as early as 2025. All these projects can be seen to be inspired by the pioneering achievements of NASA's Space Shuttle programme.

Melissa Brobby is a science communicator and social media lead at the Institute of Physics

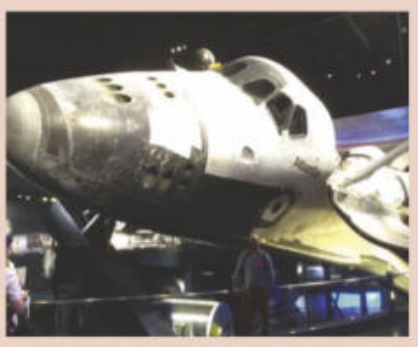
The Shuttles' new life in retirement

The four remaining Space Shuttles are on public display in museums across America

ENTERPRISE, the first Shuttle, which never flew into space, is on display at New York's Intrepid Sea, Air & Space Museum.

DISCOVERY, the Shuttle that launched the Hubble Space Telescope can be found at the Steven F Udvar-Hazy Center in Chantilly, Virginia.

ENDEAVOUR was the first Shuttle to be built after the Challenger disaster. It can be visited at the California Science Center in Los Angeles.



ATLANTIS, the last Space Shuttle to fly in space, is on display at the Kennedy Space Center Visitor Complex at Cape Canaveral, Florida.

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Make your own model of the Milky Way

Increase your knowledge about our home Galaxy and the location of the Sun

A yellow mini-pompon indicates the Sun's position on the Milky Way model

A highlight of summer nights is seeing the Milky Way stretching across the sky. Its name is a translation of the Latin *via lactea*, meaning 'milky road', which perfectly describes its appearance from Earth. Over the centuries our knowledge of the Milky Way has changed considerably. It wasn't until Galileo pointed his telescope at the Milky Way that we discovered that it's made up of individual stars; and it was believed for ages that it contained all the stars in the Universe, with our Sun at its centre. Next, in the 1920s, the Milky Way was found to be one of many galaxies. Visually, we could see that it must be a flattened disc of stars, but other details were still a mystery.

Astronomers have since studied the Milky Way with techniques encompassing optical, radio, infrared and X-ray wavelengths and we now have a much clearer picture of our home Galaxy. We believe it is a barred spiral, with a diameter around 100,000 lightyears. This size is approximate as there is no fixed outer boundary. Also, we now know that our Sun is located on a spiral arm – around 25,000–30,000 lightyears from the Milky Way's middle. The Galaxy itself is made up of a nucleus with a massive black hole at the core. Around this is a spherical bulge of stars and globular clusters. The disc contains stars and gas clouds, and this includes a central bar and spiral arms – and these contain a higher density of stars, star-forming regions and interstellar gas and dust.

ALL PICTURES: MARY MCINTYRE

Mary McIntyre is an outreach astronomer and teacher of astrophotography

Galaxy quest

In this family-friendly project we are making a model of the Milky Way so you can explore our Galaxy from your home. Each step provides a learning opportunity, and all you need to get started is a good reference photo of the Milky Way (see below for details on how to download one) and some basic craft materials. Making the model larger makes it easier to add fine details, but because A3 black craft foam craft sheets (or cardboard) may be harder to find, we joined two A4 sheets together. We have a black mini-pompom at the centre for our black hole; you won't see it in the finished model, but you'll know it's there!

To represent the different components of the spiral arms we are using coloured glitter glue plus chalk dust mixed with lustre dust for extra sparkle. A yellow mini-pompom marks the Sun's position. (Please don't wash glitter down the sink where it can pollute our oceans.)

After completing this project, you'll be much more familiar with our place in relation to our home Galaxy!

MORE **ONLINE**

Download a reference image of the Milky Way that shows its spiral arms. See page 5 for instructions

What you'll need

- Five A4 black craft foam sheets; we used four sheets for the disc and one to create a display stand.
- Cotton wool – this will be used to create the spiral arms and the central bulge of the Galaxy.
- Two mini pompoms: a black one (black hole) and a yellow one (Sun).
- Different coloured glitter glue to represent the different stars and star-forming regions along the spiral arms. We also used nail varnish with silver and gold particles and lustre-dust used in cake decorating.
- A reference picture showing the Milky Way's spiral arms.

Step by step

Step 1

Cut two circles with a diameter of about 26cm from the black craft foam. We made each one by joining two A4 pieces together along the long edge using double-sided tape; we then drew around a dinner plate and cut out the circles.

Step 2

Join the two circles using double-sided tape with the seams at 90° to each other. Then use a chalk or pastel pencil to lightly trace out the shape of the central bar and spiral arms of the Galaxy. Use our downloadable reference picture as a guide.

Step 3

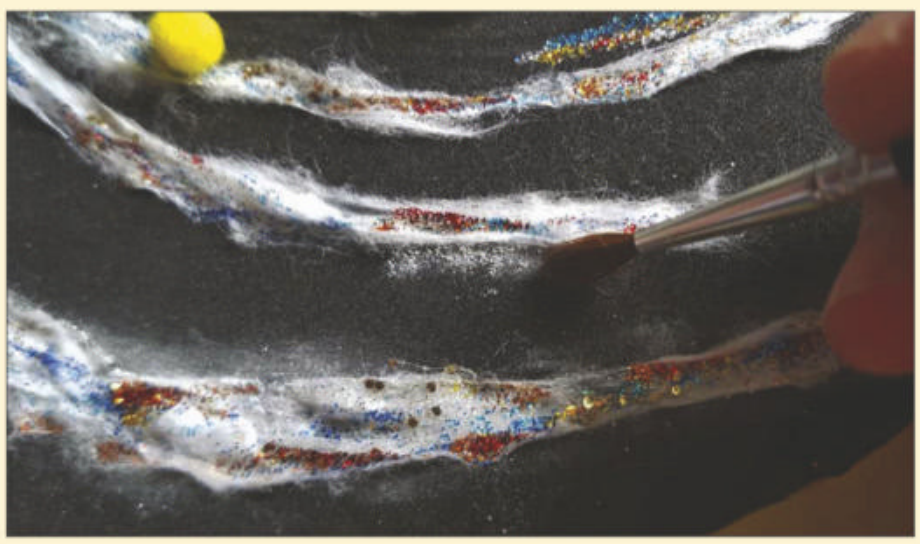
Stick the black hole pompom in the centre of the disc. Tease out the cotton wool into thin strands and glue them along the spiral arms using PVA glue. Next, glue cotton wool over the black hole and along the central bar, adding more to form the central bulge.

Step 4

Use different colours of glitter glue and glitter nail polish to recreate the star distribution seen in your downloaded Galaxy reference image, paying attention to the different star colours. Next, glue the yellow Sun pompom in place.

Step 5

Roll the final foam sheet into a tight cone and stick it in place with double-sided tape and staples. Trim the base of the cone so it sits flat and cut off the top at an angle. Using hot glue, stick the disc onto the base.



Step 6

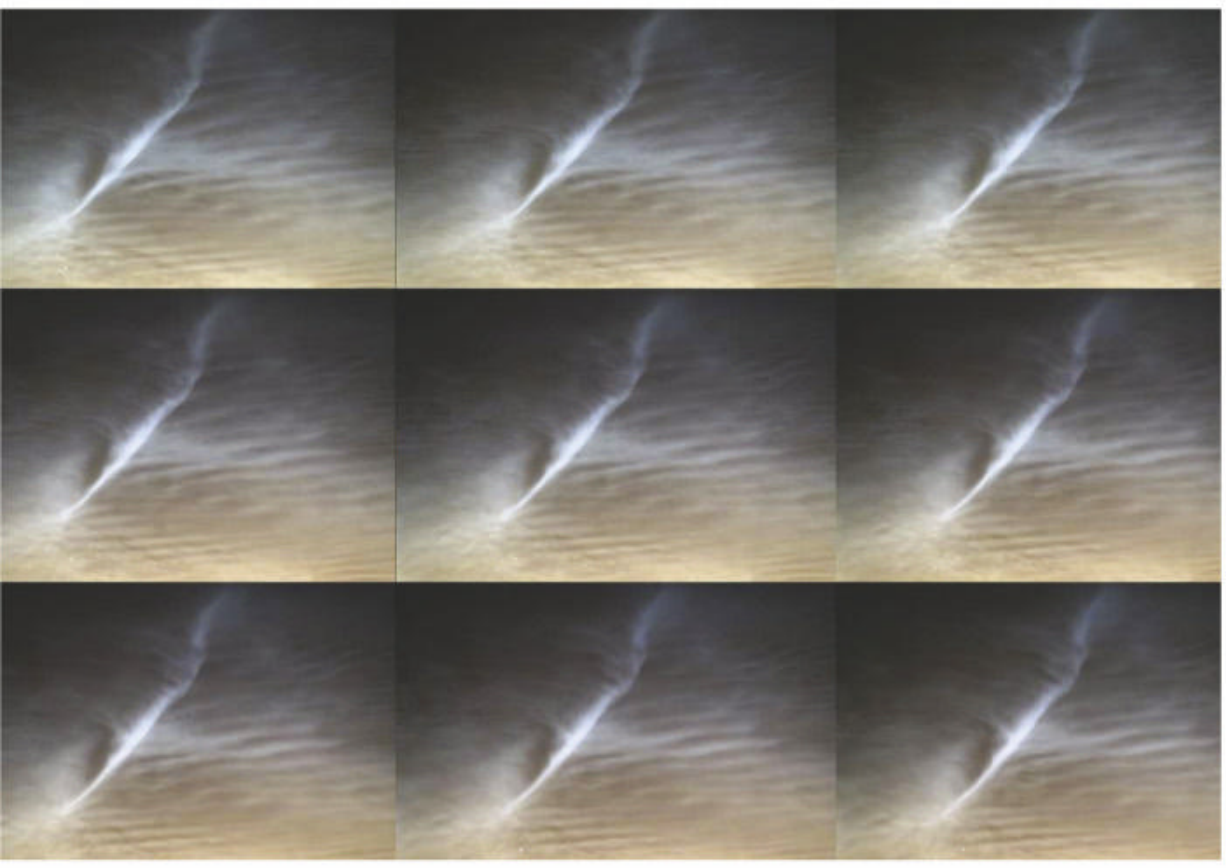
Scrape some chalk dust into a pot and mix in some lustre dust. Use a dry, fluffy brush to dab the dust along the edges of the spiral arms and blend it gently into the foam; this will remove harsh edges and add some extra sparkle.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Taking scientific images of NLCs

Use camera settings and simple techniques to record valuable data about displays



▲ **By taking a sequence of shots of NLCs, you will discover how the clouds vary and move as a display develops**

ALL PICTURES: PETE LAWRENCE

At this time of year we normally get excited about seeing and imaging noctilucent clouds (NLCs). If you have seen a display before, you'll know how addictive NLC-observing can be; whether it's witnessing the beauty of a bright NLC display, or the sense of anticipation about whether a display will be visible despite the unpredictable weather. These factors combine to make this a compelling phenomenon to observe. On the other hand, if you haven't seen an NLC display, you may be wondering what all the fuss is about. After all, astronomers and clouds don't mix well – do they?

In this instance they do, especially as NLCs can be considered to be a bridge between meteorology and astronomy. Ice crystals form in a narrow layer within the mesosphere, 82km up, seeded primarily from meteor dust; the debris of a meteoroid vaporising within Earth's atmosphere. At their great height, some seven times higher than the highest regular (tropospheric) clouds, NLCs are able to reflect sunlight after the Sun has set for us on the ground.

Too tenuous to be seen during regular daylight, as the sky darkens the delicate glow of NLCs may appear against the twilight vignette. Typically, if present they can be seen at low altitude above the northwest horizon from 90–120 minutes after sunset, and a similar time above the northeast horizon before sunrise. They don't always play by the rules, however, and may be seen at mid, or even high altitude under certain situations. They may also remain visible over the night, tracking the Sun's position below the horizon, passing from the northwest, through north, until they fade in the northeast as dawn approaches.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Scientific interest

NLC structure, complexity and brightness can vary and there are no guarantees they will be visible – but that's part of the attraction. If NLCs are visible, a camera can record important information. As well as taking visually appealing shots of NLC displays, with a little extra effort you can turn your images into a scientific record, and help to further our understanding of NLCs.

NLCs are ideal targets for digital stills cameras with manual controls. Bright displays may also be recorded by smartphone cameras. Ideally, a mid- to wide-angle lens is best, but narrow-angle solutions may provide valuable information about how the clouds move and vary. A narrow-angle solution is achieved by using a telephoto lens, or with a camera attached to a scope.

All options can be achieved with fixed mounting platforms such as a tripod. Just follow our simple steps opposite to augment those 'pretty' shots with something of real scientific importance.

Recommended equipment: stills camera: DSLR, MILC or smartphone; tripod, remote shutter release

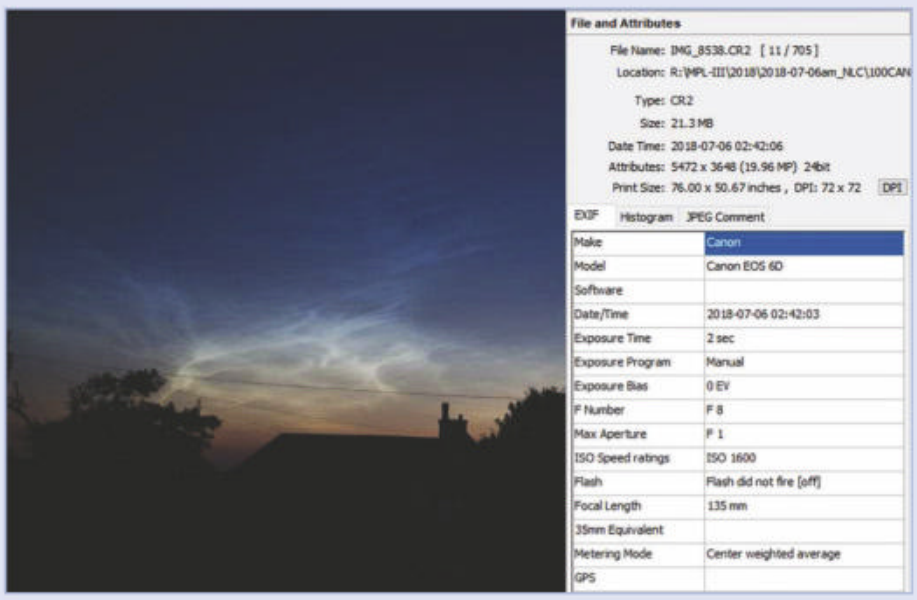
▸ **Read more about noctilucent clouds on page 47**

✉ **Send your images to:**
gallery@skyatnightmagazine.com

Step by step

STEP 1

One of the simplest and most often overlooked things that can turn an image into a scientific record is an accurate date–time stamp. In order to do this, get into the habit of checking and adjusting your camera's clock before using it for astro imaging. Try and always set the clock time to UT to avoid future confusion.

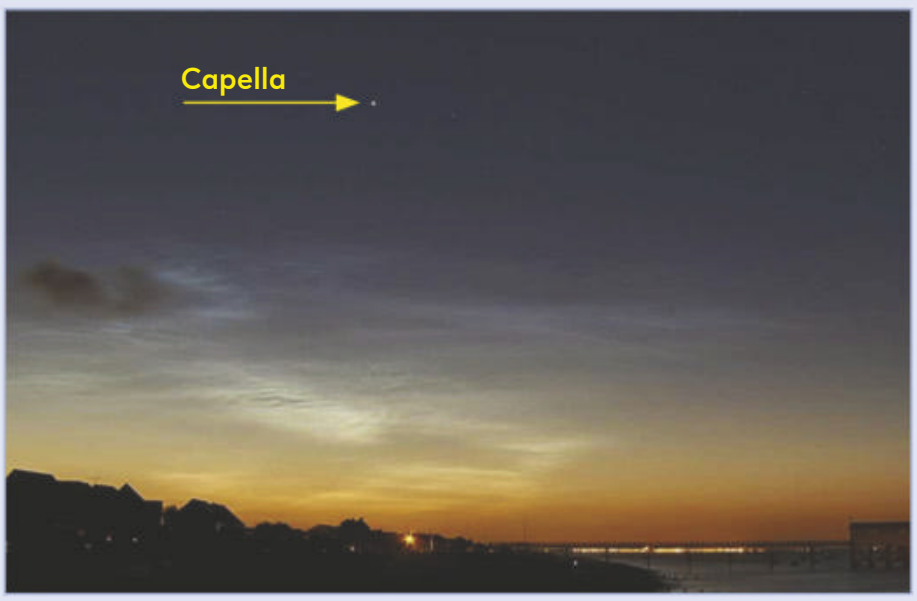


STEP 2

Modern cameras store lots of information about settings, but if you are using telescope-coupled cameras or manual lenses, this will be missing. A log book allows you to record this, and image viewing programs like FastStone Viewer (**faststone.org**) allow you to view all the important EXIF data held about an image.

STEP 3

Accurate focus is important whatever the subject. For NLCs it allows you to record intricate details within the display, which can alter over time. Accurate focus can be achieved by setting your lens focus mode to manual and adjusting focus on a bright star or planet. Use 'Live View' at maximum magnification if available.



STEP 4

Recording the altitude of NLCs is important and the photogenic star Capella is well placed for measuring it. First, record your location accurately; the date and time information will then allow Capella's altitude to be determined from a planetarium program (eg Cartes du Ciel, **ap-i.net/skychart/en/start**).

STEP 5

NLCs are a deep twilight phenomenon, so it's important to monitor settings to avoid under- or overexposure. Aim to keep exposures lower than 10" and ISO settings low. This reduces image noise and improves tonal quality. Use your camera's RAW format to remove post-capture image manipulation.

STEP 6

Animated sequences can provide valuable information about structure development in NLCs. Frame a shot with a bit of horizon at the bottom, then fix the camera's pointing position and take a sequence of shots every 5 to 10 seconds. Load these into an editor that supports animation timelines (eg Photoshop or GIMP).

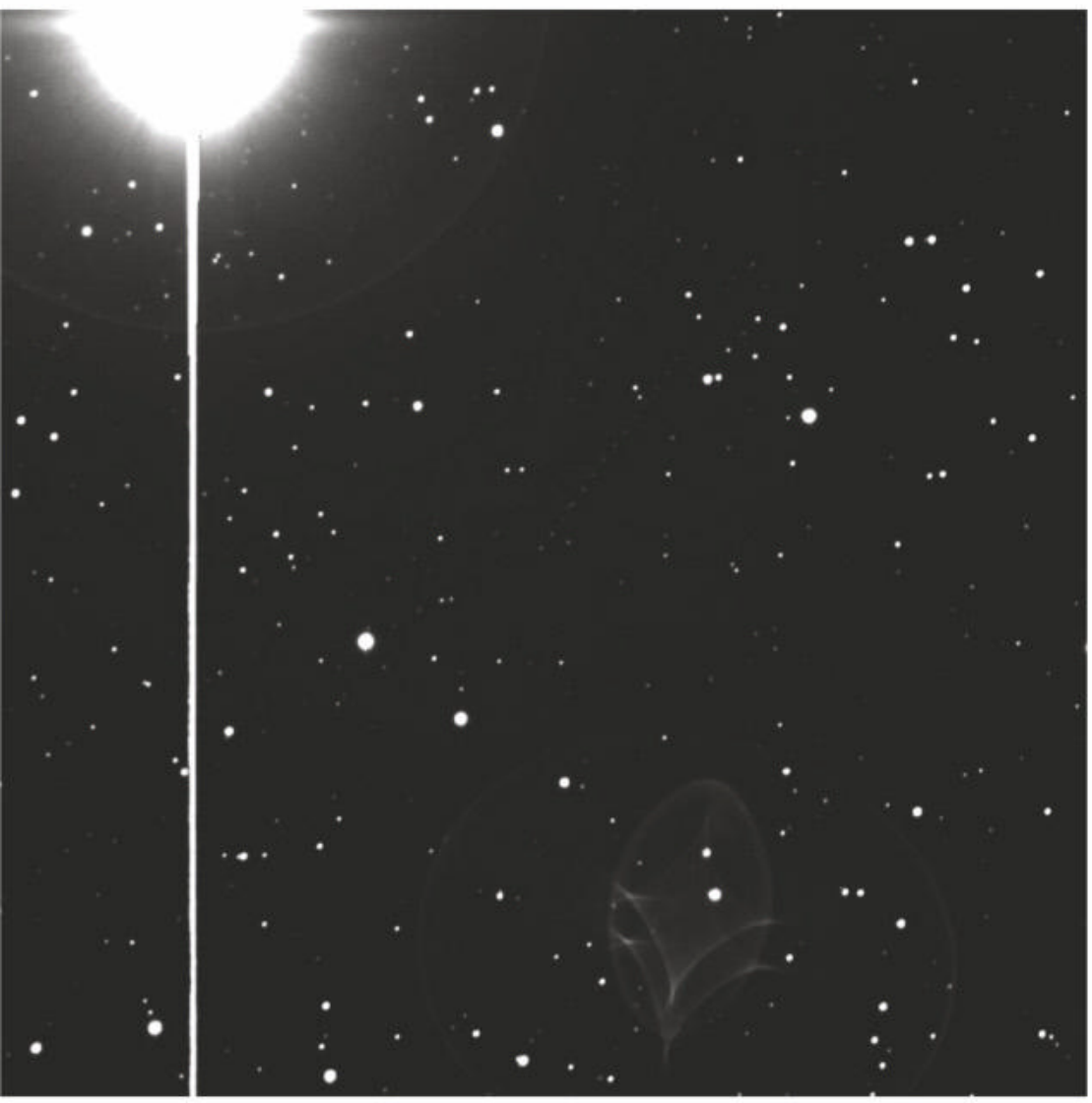
APY Masterclass

Showing the motion of an asteroid

How to stack a series of asteroid images to add drama to a picture

Astronomy Photographer of the Year

Advice from a 2020 shortlisted 'Planets, Comets and Asteroids' entrant



◄ The overexposuse of star Alnilam (top left corner) was turned to advantage in 'Ghost of Alnilam and a Near Earth Asteroid', a highly commended image in the APY 2020 awards

ALL PICTURES: ROBERT STEPHENS

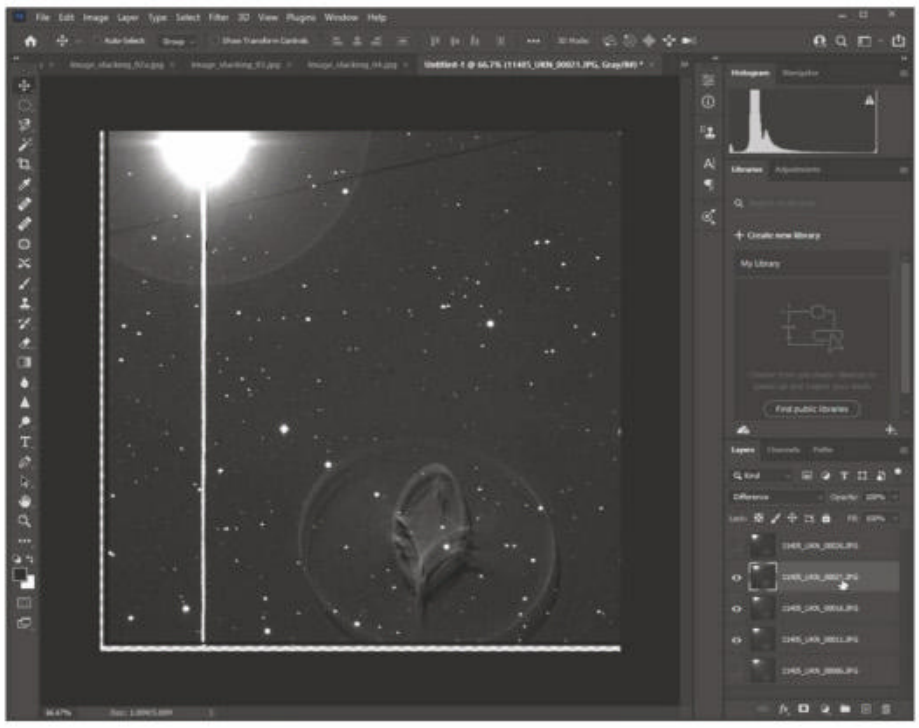
There's a popular proverb that states 'when life gives you lemons, make lemonade'. Such was the case when I used some of my nearly spoiled images of the near-Earth Asteroid (11405) 1999 CV3, which I'd originally taken for scientific modelling purposes, to create an artistic composition. This opportunity arose because I operate several remote, robotic telescopes at the Center for Solar System Studies (CS3) in Southern California and take time-series images of asteroids to model their properties. One morning I opened a set of 77 images of a near-Earth asteroid and I thought they had been ruined by the bright, middle star of Orion's Belt, Alnilam (Epsilon (ε) Orionis), which was in the field of view. However, I realised that the reflection of this second magnitude star would make an interesting composition, particularly when I stacked a sequence of the near-Earth asteroid moving across the centre – and this became my APY entry. In this article I'm going to explain how I used stacking to create this effect.

Get stacking

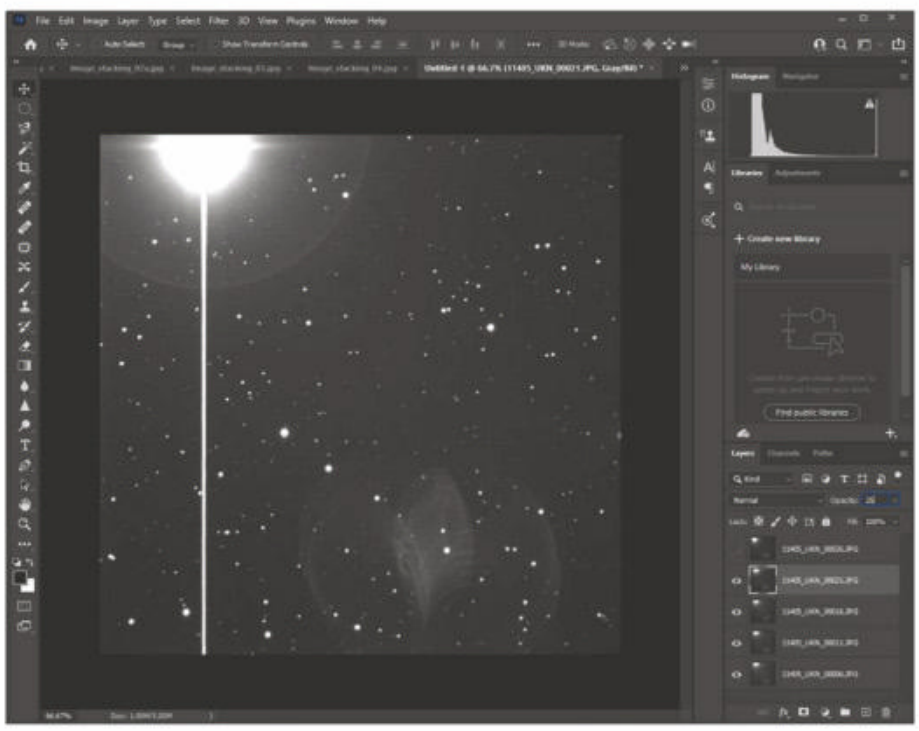
To show an asteroid moving, you first need to decide how many images to stack. Stacking dozens of them into a single image will show a streak of the movement throughout the night, but my image only used every fifth image, with 16 in total, to show a dotted pattern of movement. If you have a large number of images to stack, programs such as CCDStack work well. In this case I used Adobe Photoshop as there were only 16 images to stack.

The first step is to load the images in Photoshop by selecting 'File › Scripts › Load Files into Stack'. If any image needs alignment (see Screenshot 1), select it in the 'Layers' panel and use the dropdown menu under 'Blend Mode' to select 'Difference'; you can then nudge the image with the 'Move' tool. At this point you might combine a few of the images to reduce the background noise (unwanted artefacts) by leaving the 'Opacity' as it is on the base layer, but then setting the 'Opacity' to 50%, 33%, 25% and 20% on layers 2-5 respectively. Next, combine those layers by selecting 'Layer › Merge Layers'. For this composition I didn't use a blended base layer because the telescope was tracking the asteroid, causing the internal reflection to shift between images.

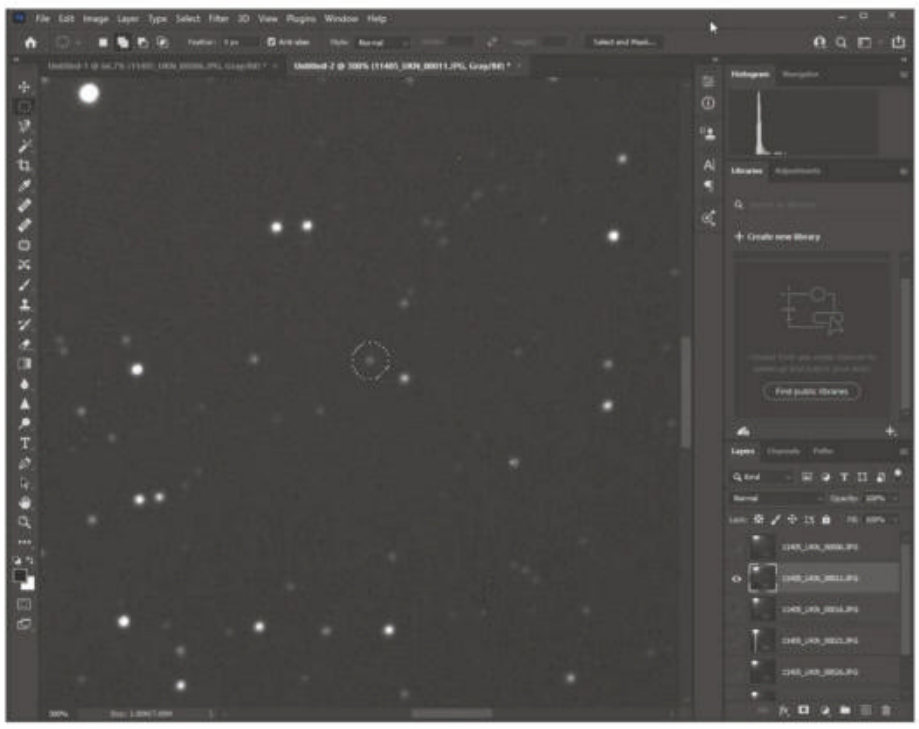
The next stage is to combine the stack of 16 images. You might think about setting the 'Blend Mode' to 'Difference' and the 'Opacity' to 100%, but this will bring through all the noise and imperfections from every image to the final picture. Instead, use a base image – your blended image if you created one (see Screenshot 2) – and only add the region immediately around the asteroid from each subsequent image. Go to the



▲ **Screenshot 1: Images can be aligned in Adobe Photoshop**



▲ **Screenshot 2: Blend the background around the asteroid**



▲ **Screenshot 3: Copy the asteroid and the selected area around it**

second image, zoom in, and use the 'Elliptical Marquee Tool' to draw a circle around the asteroid.

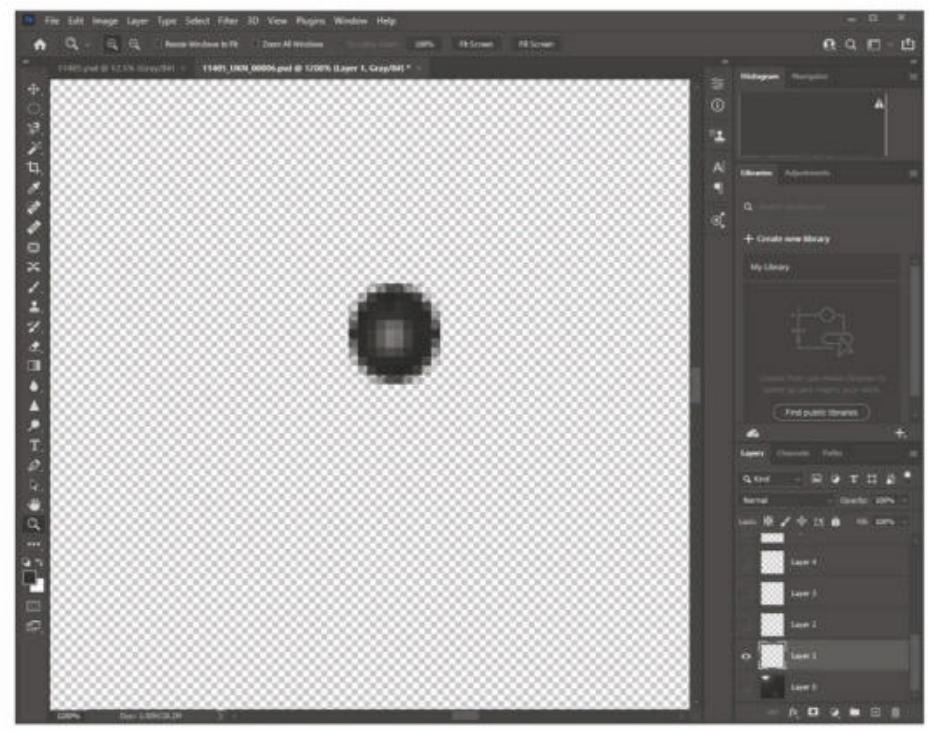
Next, use 'Select > Modify > Feather' to feather the selection area, which creates a soft blending edge. To copy the region (see Screenshot 3), click 'Edit > Copy' and use 'Edit > Paste Special > Paste in Place' to create a new layer with just the area around the asteroid (see Screenshot 4). Repeat for the remaining images.

Finally, delete all of the original asteroid image layers except for your base layer and the new layers with the copied area around the asteroid.

Before you flatten the image into a single layer, each layer might need some tweaking using the 'Levels' or 'Curves' adjustment so that the backgrounds match. Also, if the asteroid's brightness was changing over time, additional adjustments might be needed. In this case, since the asteroid's brightness was mag. +16.5 and varied by 0.55 magnitude over the night, I increased the 'Contrast' and 'Brightness' for each of the individual asteroid images to make it more apparent in the final stack. Finally, click 'Layer > Flatten Image' to combine all the images into a single layer. Crop the image if needed and perform any final 'Contrast' and 'Brightness' adjustments.

This technique also works for combining meteors into a single frame, but use one of the 'Lasso Tools' instead of the 'Elliptical Marquee Tool' to trace each meteor.

The final picture (see main image, left), entitled 'The Ghost of Alnilam and a Near Earth Asteroid', presents a ghostly scene. In the top left corner is Alnilam, which is 2,000 lightyears away, and in the lower right is an internal reflection from the star, which looks a bit like an alien. In the middle is the dim asteroid, which is just 126 million kilometres from Earth.



▲ **Screenshot 4: Paste into a layer with just the area immediately around the asteroid**

3 QUICK TIPS

1. Avoid using images where the asteroid is entangled with a background star.

2. Zoom in on the asteroid when selecting it and make sure the background matches the base image.

3. Depending on the brightness of the asteroid, increase the contrast and/or brightness of the pasted layer.

Robert Stephens is a California-based astronomer. He was highly commended at the APY for 'The Ghost of Alnilam and a Near Earth Asteroid'

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

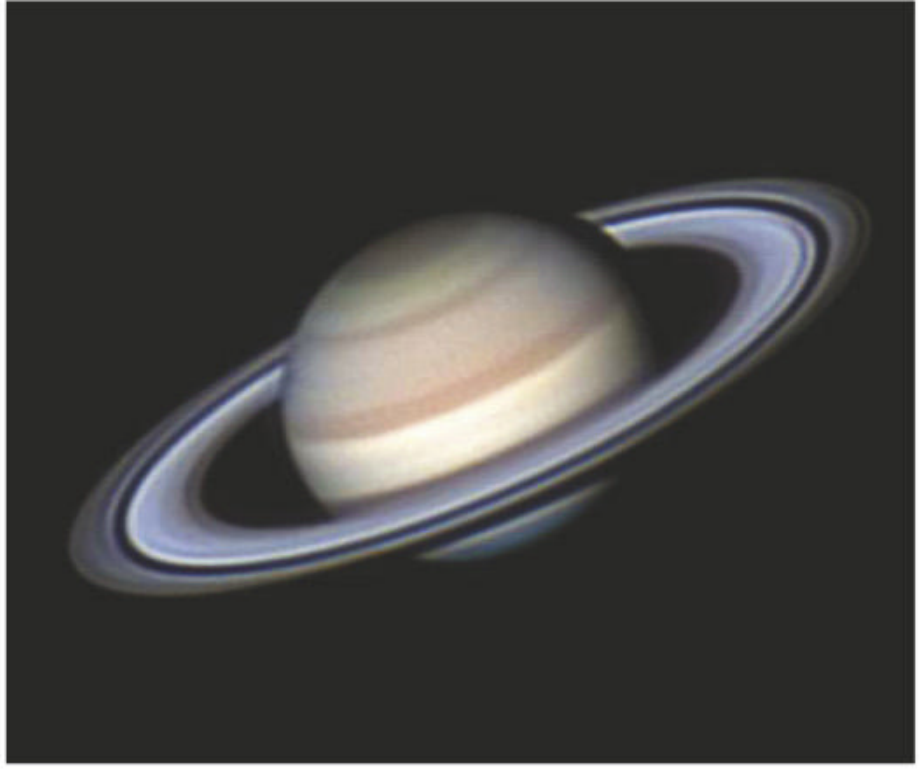
▽ The Leo Triplet

Peter Rea, Appley Bridge, Wigan, 16 March 2021

Peter says: "I took up astrophotography six months ago. This was taken from my back garden on one of those rare nights in the UK when it was clear all night. I was pleased with the level of detail that came through from just 4.5 hours of imaging time."

Equipment: ZWO ASI 533MC Pro cooled colour camera, Altair 72mm EDF refractor, Sky-Watcher HEQ5 mount
Exposure: 69x 240'
Software: APP, Affinity Photo

Paul's top tips: "As I'm just starting out in astrophotography, my advice is to get the basics right. Set up in daylight if possible, taking your time to make sure the balance of the scope is correct and that you have good polar alignment. Ascertain when your target object rises and sets to get the most imaging time. Take some test shots for framing your target. Finally, when you're processing, start again if you're not happy with the first results."

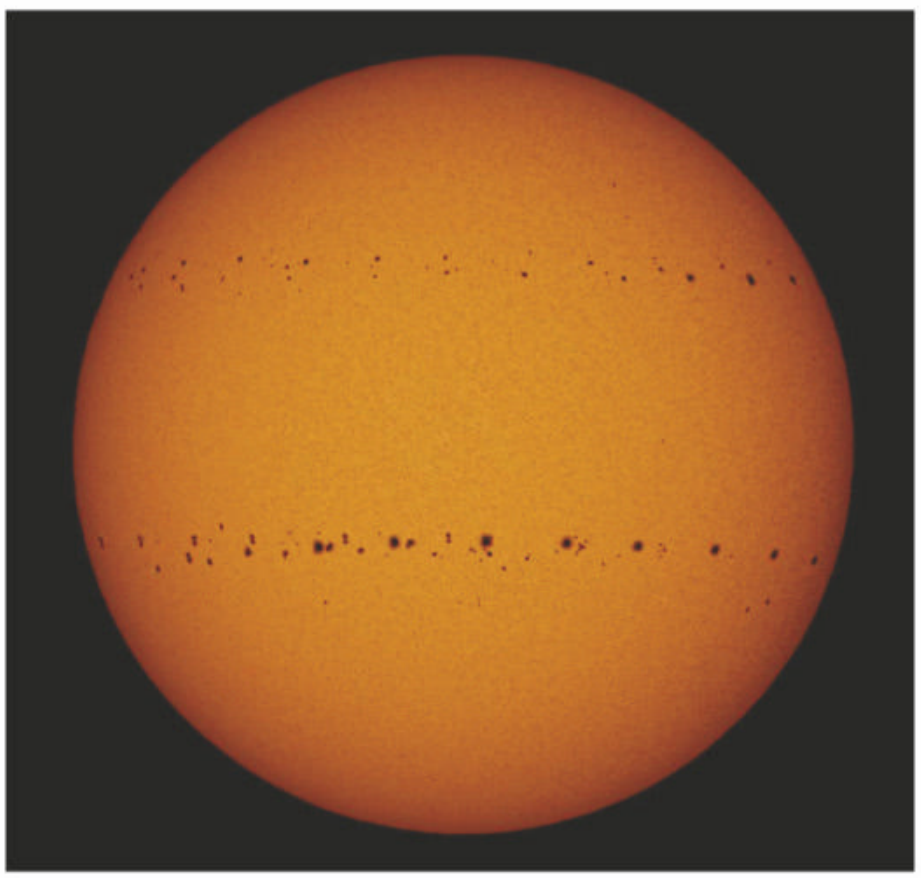


Saturn ▷

Eric Sussenbach, Willemstad, Curaçao, 25 April 2021

Eric says: "Saturn will always amaze us. I will never forget the first time that I saw the planet and its rings though my first telescope. I am very happy with this capture so early this year."

Equipment: ZWO ASI 462MC colour camera, Celestron 11-inch EdgeHD Schmidt-Cassegrain telescope, Celestron AVX mount **Exposure:** 90" video **Software:** FireCapture, PIPP, AutoStakkert!, RegiStax, WinJupos, Photoshop



△ Bode's Galaxy

Rouzbeh Bidshahri, Vancouver, Canada, 15 March–17 April 2021

Rouzbeh says: "Even though it's one of the larger and relatively bright galaxies, Bode's still poses considerable challenges. The ever-growing presence of light pollution and human-made satellites are major hurdles."

Equipment: QHY268M mono CMOS camera, CFF 250mm Cassegrain reflector, 1100 GTO mount **Exposure:** L 184x 180", R 74x 300", G 76x 300", B 81x 300" **Software:** NINA, PixInsight

◁ 100 Days of Sunspots

Soumyadeep Mukherjee, Kolkata, India, December 2020–April 2021

Soumyadeep says: "This is a composite of 100 images taken over 100 days in a row, showing every sunspot that appeared: a total of 19 active regions, clustered in two narrow bands, 25° north and south of the equator."

Equipment: Nikon D5600, Sigma 150–600mm lens, tripod **Exposure:** 1/80"–1/250" **Software:** PIPP, Camera Raw, Photoshop

◁ Orion at Ribblehead

Pete Collins, North Yorkshire, 15 April 2021

Pete says: "This is me and my dog Bella watching Orion setting behind the ridge of Whernside (one of the Yorkshire Three Peaks), under an arch of the iconic Ribblehead Viaduct."

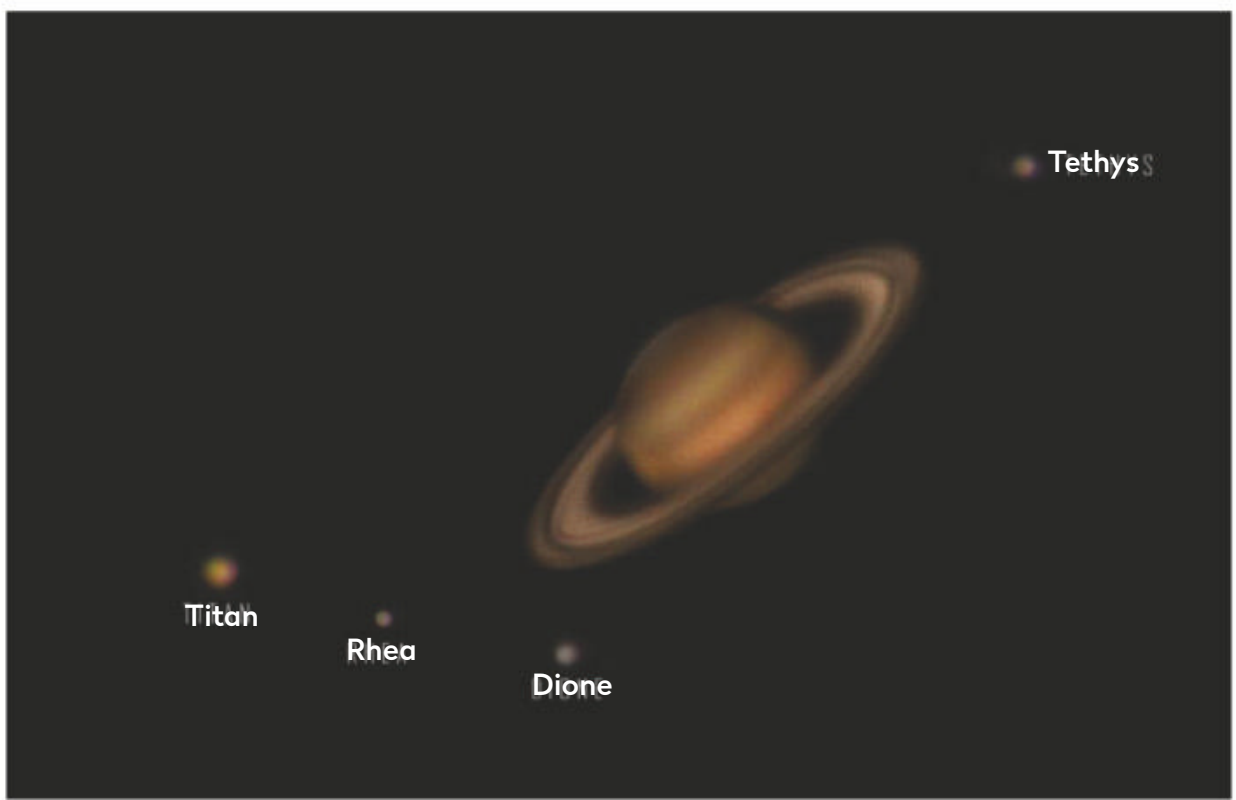
Equipment: Canon 6D DSLR, Samyang 24mm lens, tripod **Exposure:** ISO 100 f/2, 25" **Software:** Lightroom, Photoshop

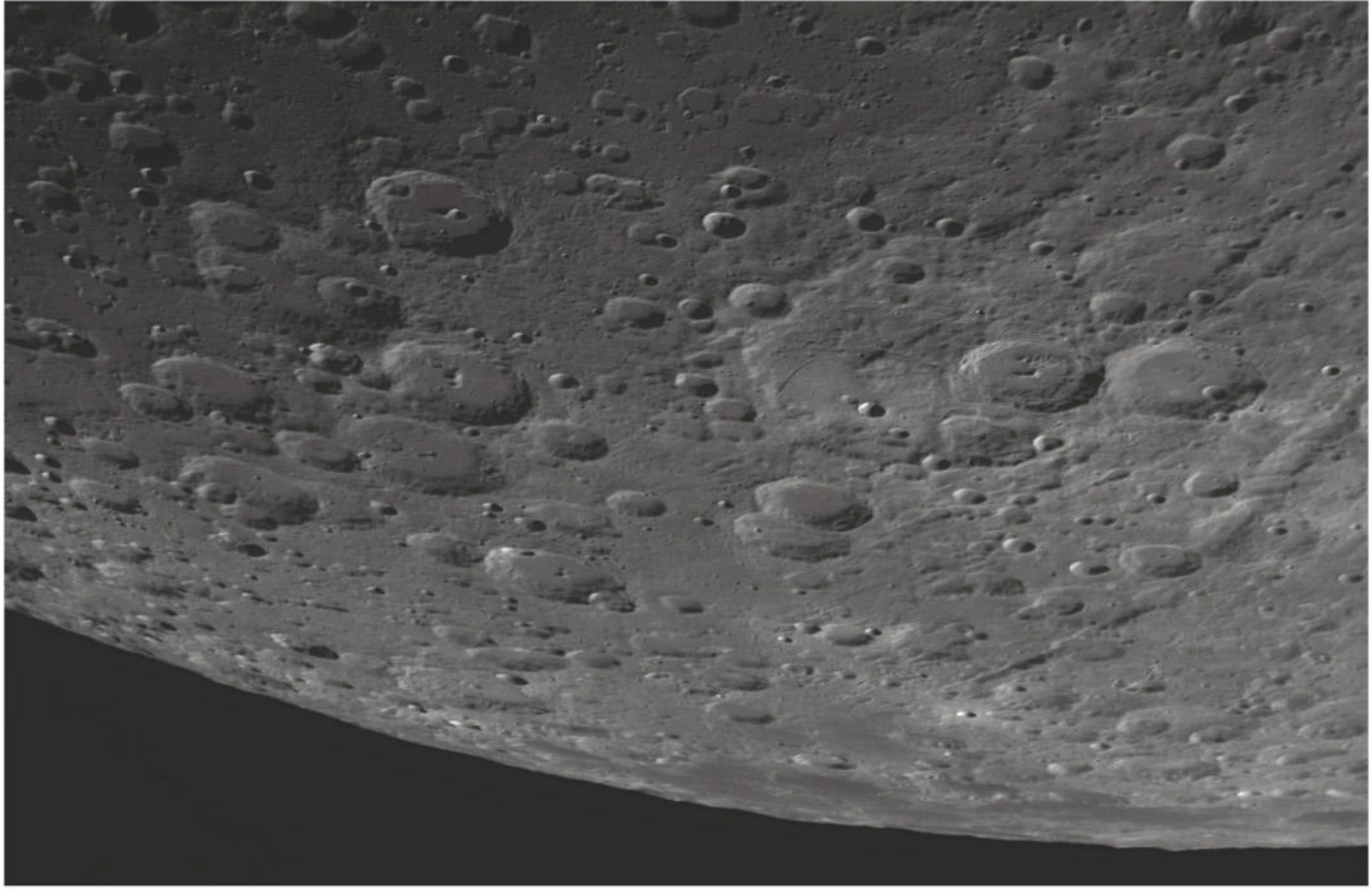
Saturn and its moons ▷

Sreesha Belakvaadi, Bangalore, India, 1 May 2021

Sreesha says: "This ringed beauty, 1.5 billion km away from Earth, is quite unstable to capture with a 2,350mm focal length. I had to use video as a base and pick the best frames to stack."

Equipment: ZWO ASI290MC colour camera, Celestron 9.25-inch SCT, iOptron CEM40 mount **Exposure:** 90" AVI video capture; gain: 90 (Saturn), 283 (moons) **Software:** SharpCap, Photoshop





△ The Moon's southern highlands

Luke Oliver, Bedford, 18 April 2021

Luke says: "I noticed the crescent Moon was high in the sky, so I tried to get a decent snap. It's the sharpest view of crater Janssen I've captured."

Equipment: ZWO ASI 178MM mono camera, Sky-Watcher Skyliner 400P **Exposure:** 58.42ms, best 500 frames stacked **Software:** FireCapture, AutoStakkert!, RegiStax

Statue of Liberty Nebula ▷

Alexander Curry, remotely via El Sauce Observatory, Chile, 21 March 2021

Alexander says: "I've never imaged this nebula before, and I hope you agree it came out great!"

Equipment: FLI PL16803 CCD camera, Planewave CDK24 astrograph, Mathis MI 1250 mount **Exposure:** 4x 300" Ha, SII, OIII **Software:** PixInsight, Topaz Labs Denoise AI

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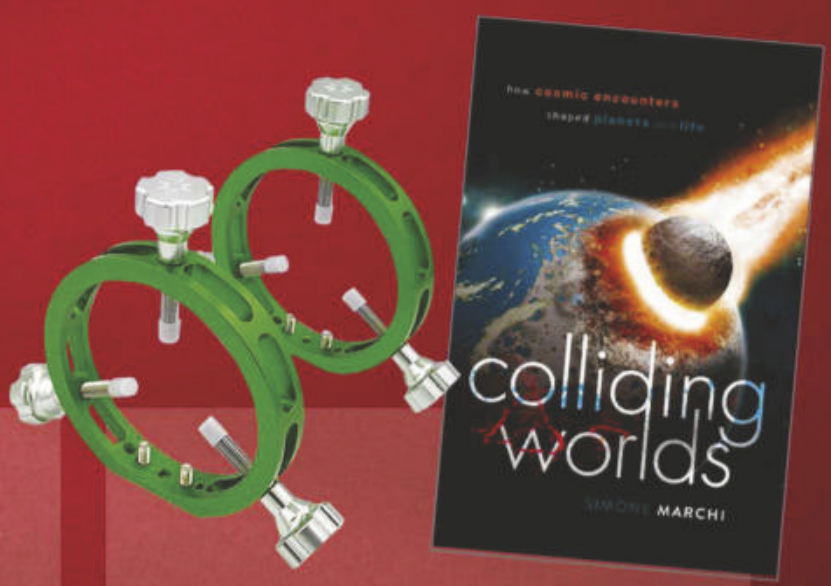
More than meets the eye: Canon's EOS R6 mirrorless camera boasts a 20MP sensor and fast video capture



HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

PLUS: Books on asteroids and what we can learn from planetary impacts, plus the latest astronomy accessories

FIRST LIGHT

Canon EOS R6 mirrorless camera body

A full-frame mirrorless camera with a superior sensor and fast video capture

WORDS: CHRIS GRIMMER

VITAL STATS

- **Price** £2,599.99
- **Sensor** 35.9mm x 23.9mm, 20MP full frame CMOS
- **ISO range** 100–102400, expandable to 204800
- **Live View** Magnify image by 5x and 10x for manual focusing
- **High frame rate** Full HD at 100fps
- **Body size** 138.4mm x 97.5mm x 88.4mm
- **Weight** 680g (without a lens)
- **Supplier** Canon UK
- **Tel** 020 7660 0186
- **www.canon.co.uk/cameras/eos-r6**

ALL PICTURES: @THESHED/PHOTOSTUDIO

The Canon EOS R6 is a full-frame mirrorless camera that features the latest incarnation of Canon's classic 20 megapixel sensor. This offers an ISO range of between 100 and 102400, expandable to 204800, while maintaining low noise (levels of unwanted artefacts) into the mid- to high range of ISO settings. Canon hasn't followed the recent trend of 'the more megapixels the better', instead opting to keep the bigger pixels provided at 20MP, which works well very for astrophotography.

The camera's magnesium alloy body is reassuringly sturdy and solid, weighing in at 680g, which is lighter than its mirrored, full-frame equivalent. The Canon R series cameras use the new RF lens mount and a new range of RF lenses are available. However, with the use of an optional adaptor, purchased separately, the R series cameras are fully compatible with Canon's EF and EF-S-type lenses.

For regular Canon users, it's good to see the company has maintained the familiar layout of previous models. The Mode Dial remains on top of the camera, allowing you to switch between modes in the dark with ease. As with several of its predecessors, the R series also uses the touch screen as its main control surface, which we found simple to navigate, as long as we weren't wearing gloves. We were loaned two lenses for the review – a Canon 15-35mm f/2.8 L and Canon 24-240mm f4/6.5 – and a Canon EF-EOS R adaptor, which allowed us to use the camera with our 80mm refractor to test its performance on a selection of deep-sky objects.

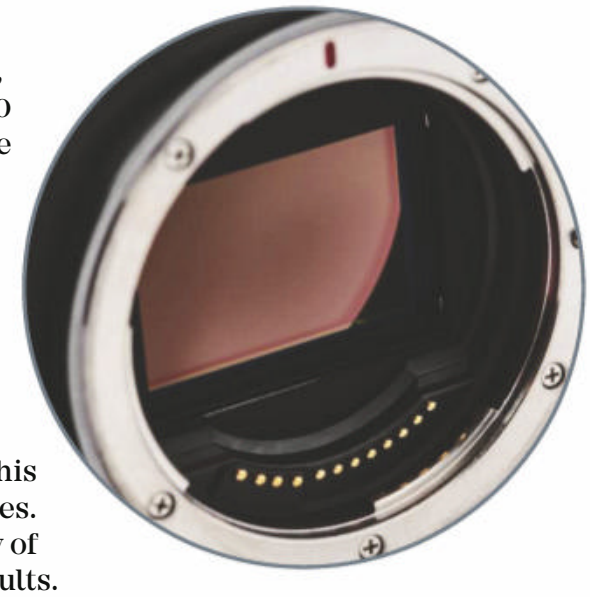
The Canon EOS R6 arrived at full Moon, which gave us the perfect opportunity to try out one of its main features: the fast video capability. The camera can shoot in 4K resolution at up to 25 frames per second (fps), but its party piece is a high-speed video option that can achieve in excess of 100fps, which is a highly respectable speed for lunar and solar imaging. Movies are recorded in MP4 format, meaning they can be converted and read by most planetary-stacking software. One disadvantage is that the file size is restricted to 2GB in size, which limits video length.

Thanks to the large high-resolution LCD screen and a two-stage zoom (5x and 10x), focus was achieved easily, and at higher ISO settings we found that even severely out of focus stars were easy to ▸

State of the art sensor

The EOS R6 has Canon's latest 20 megapixel full-frame CMOS sensor, which boasts a greater than average ISO range that goes up to 204000 – most barely reach a quarter of this. Images produced at this ISO are noisy (full of unwanted artefacts) and are not suitable to run at long exposures; so the ability to run short exposures at this setting allows for easy and quick target-alignment. It means that nebulosity becomes visible without waiting for a long exposure to finish.

The sensor comes into its own with wide-field astro imaging, as the Canon EOS R6 proves to be very sensitive in low light. RAW images taken straight from the camera, using ISOs as low as 1600, clearly show details in the Milky Way. Even when we pushed the ISO up to 6400 we found the images contained very little noise, making this an ideal setting for shorter, untracked night sky and Milky Way images. This made the processing a breeze, with very little needed in the way of noise reduction or image manipulation in order to gain beautiful results.



Video function

The video-capture mode allows for shooting up to 120 frames per second. This makes it a respectable option for lunar or solar imaging where other DSLR variants can struggle. The MP4 file can be easily converted for use in most stacking software. However, they are very large files.

Mirrorless camera

Canon's R series cameras are mirrorless, so unlike traditional DSLRs the viewfinder is also a small LCD and displays exactly what the sensor is seeing. The big advantage of a mirrorless system for astrophotography is that it removes the chances of mirror shake and therefore reduces vibration and noise (unwanted artefacts) during image capture.

Articulated LCD screen

A large 3-inch, fully adjustable LCD screen allows you to adjust all the camera settings in one place. The brightness of the screen can be adjusted so that it doesn't dazzle you or others in the dark, and its core menu layout is reminiscent of its classic Canon predecessors.

Touch screen

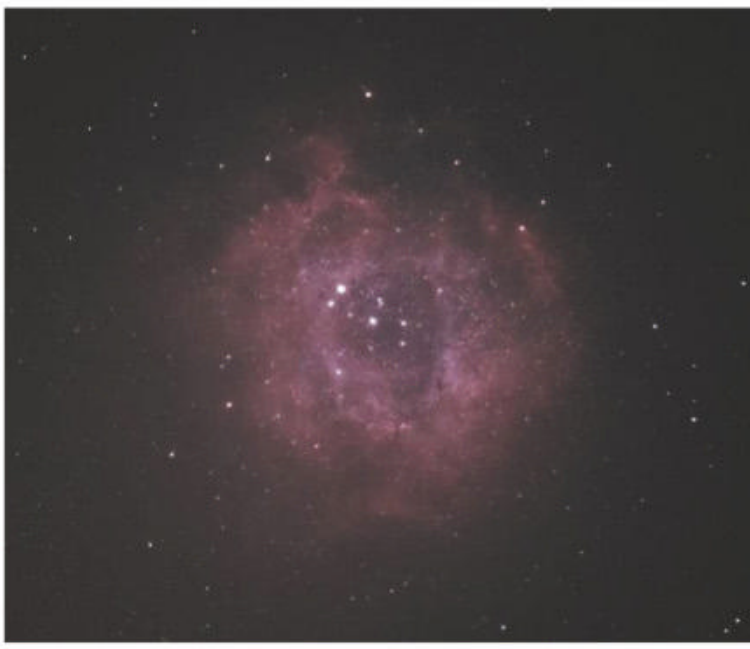
We found the touch screen to be very sensitive, allowing its use as a shutter with only the gentlest of touches. All the settings can be found easily and selected via the touch screen, without the need to press any physical buttons, helping to reduce the risk of camera movement.

FIRST LIGHT

Connectivity

The Canon EOS R6 has wi-fi and Bluetooth connectivity and it's very simple to connect to via a phone. While both options allow for full exposure control, the camera is also fitted with a high-speed USB C port, allowing direct operation via a laptop and your own preferred imaging software.

An eight-panel Milky Way mosaic, taken with the Canon EOS R6, using 30" exposures at ISO 3200



▲ The Rosette Nebula, taken with the Canon EOS R6 and a William Optics GT81 refractor – using a HoTech field-flattener – with 182x 30" exposures at ISO 1600

©THESHED/PHOTOSTUDIO, CHRIS GRIMMER X 2

▸ spot. Partnered with a short focal length refractor, the Canon EOS R6 gave a wide field of view, which allowed us to capture large objects such as the Rosette Nebula, NGC 2244. The process of finding and aligning on the Rosette Nebula was easy, and the star cluster in the centre was clearly visible in the 'Live View' screen. Taking a short exposure at a high ISO revealed the faint nebulosity, while dropping the ISO to 3200 and taking a 30-second exposure gave a clean, low-noise image with clear detail visible. To reduce the noise (unwanted artefacts) further, we decided to drop the ISO to 800 and left the camera running, taking 30-second exposures for two hours.

We stacked the resulting images in Sequator – minus calibration frames – and then stretched and processed them in Adobe Photoshop. Our resulting image was impressive for a camera that isn't designed primarily for astrophotography; the Canon EOS R6 is not modified and still has infrared-blocking filters installed. While this limited the hydrogen alpha (Ha) data, we picked up a surprising amount of good detail.

The EOS R6 really excelled when we captured the Milky Way with a wide-angle lens. Pairing the camera with the supplied Canon 15-24mm f/2.8 L lens, and then with our own Samyang 14mm f/2.8 lens, gave a beautiful wide field of view. Undeniably, the Canon L series lens provided the best results, but the cheaper Samyang lens (with the Canon EF-EOS R adaptor) still gave very pleasing images – without any obvious vignetting, but with noticeably more curvature. The RAW images we saw that were straight from the camera were impressively detailed, with the Milky Way's structure clearly visible.

Overall, we found the Canon EOS R6 was rewarding to use on a wide range of astrophotography targets, and we felt it had the potential to be a reliable workhorse. Indeed, the camera ticks a lot of boxes for both newcomers and avid DSLR users: while the EOS R6 performs well under dark skies, it also has plenty to offer for all occasions and abilities.

VERDICT

Build & design	★★★★½
Connectivity	★★★★½
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★½
OVERALL	★★★★½

KIT TO ADD

1. Canon RF 15-35mm f/2.8 L IS USM lens

2. Canon RF 24–240mm f/4–6.3 IS USM lens

3. Canon EF-EOS R adaptor

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Altair Starwave ASCENT 115 F7 ED triplet refractor

An apochromatic telescope that delivers well at the eyepiece and on camera

WORDS: TIM JARDINE

VITAL STATS

- **Price** £1,199
- **Optics** f/7, multi-coated ED triplet
- **Aperture** 115mm (4.5-inch)
- **Focal length** 805mm
- **Focuser** 2.5-inch rack and pinion; 1:10 ratio fine focuser knob
- **Extras** Tube rings, finderscope shoe
- **Weight** 7kg
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.**altairastro.com

ALL PICTURES: @THESHED/PHOTOSTUDIO

The Starwave ASCENT 115 ED from Altair Astro is an apochromatic refractor that will appeal to both observers and astrophotographers. The telescope is offered as an optical tube assembly-only package, meaning that additional accessories are required to use the telescope, such as a star diagonal and eyepieces for observing, or a field-flattener and optical reducer for photography. For this review we used our own items for observing and were loaned a Planostar 0.8x reducer from Altair Astro to use for imaging.

Refractors around the 4-inch (100mm) aperture mark are often what first spring to mind when we hear the word 'telescope' – and with good reason. For many astronomers, a telescope of this size offers the best compromise between light-gathering ability, portability and indeed, price. In fact, with its 115mm objective lens, the ASCENT 115ED offers around a 32 per cent larger aperture than a standard 4-inch lens, while maintaining the comfortable weight and balance that makes this size of telescope a pleasure to use.

Capturing galaxies

With the 'galaxy season' now upon us – and presented with the unusual combination of a clear sky and new Moon – we opted to test the ASCENT 115ED for imaging first. This was just a case of unscrewing the eyepiece clamp assembly and attaching the borrowed reducer directly to the focuser drawtube. This sensible arrangement eliminates any slop that can occur when you are using clamps alone, and it ensures a nice square fitting to the optical tube.

The telescope has a focal length that's just over 800mm, and the supplied reducer takes this down to 640mm, so we paired it with our Sony ICX694-based CCD camera, which has a relatively small colour sensor and avoids the need for a field-flattener. The resulting setup allowed us to photograph the galaxies in the context of their surroundings.

While setting up for photography we noted that the focuser drawtube extends over 90mm, and to achieve focus with our camera we used a good amount of this extension; we were pleased to note that the focuser held solidly with no droop. With a Bahtinov mask in place, we found the process of manually focusing with the fine speed controller was uncomplicated. Throughout the sessions, although the ambient temperature varied throughout the night by several degrees, only minimal adjustments were required to ▸

Superior triplet lens

On the Starwave ASCENT 115's dew shield, the abbreviation 'APO' is boldly declared in red capital letters. This refers to the telescope being apochromatic, a term coined for lens systems that are able to bring the varying wavelengths, or colours of light, to a point of equal focus. For our purposes this desirable setup means that eyepiece views will be brighter, crisper and more enjoyable, especially on bright targets such as the Moon or planets. Less capable lenses can produce unwanted rings or coloured haloes, as unfocused light spoils the view.

For astrophotography the effect is even more dramatic, as cameras are unforgiving and will reveal flaws in the colour correction of a lens, especially on bright stars. By extracting the red, green and blue channels from our images of stars and comparing the star size in pixels, we were able to see that the triplet lens in the ASCENT 115 is indeed apochromatic – all colours were brought to the same focus and the star size was pretty much identical for each channel.

Aluminium tube

The ASCENT 115 ED tube is aluminium, with a durable white powder-coated finish and black trim. This construction allows the telescope to quickly cool down to ambient temperature outside, which is important for the best views and images to be acquired. Once acclimated the telescope proved very stable during use.

Tube rings

The telescope is supplied with a 200mm Vixen-style dovetail bar and matching black tube rings with easy-to-turn knobs. On top of each of these rings there are five threaded holes where other accessories can be attached. A shoe for an optional finderscope is fitted to the focuser.

Focuser

With a smooth rack and pinion design, the entire 2.5-inch focuser rotates to allow for precise image framing or more comfortable observing positions, while the graduated drawtube and 1:10 fine focus reduction ensure that at first rough, and then perfect focus can be achieved quickly.

Dew shield

Keeping the elements and stray light away from the objective lens is the job of the extending dew shield. It extends 110mm and glides easily but firmly, the snug fit ensuring it doesn't drop down when the telescope points upwards. Likewise, the aluminium end cap holds securely in place on a felt strip.

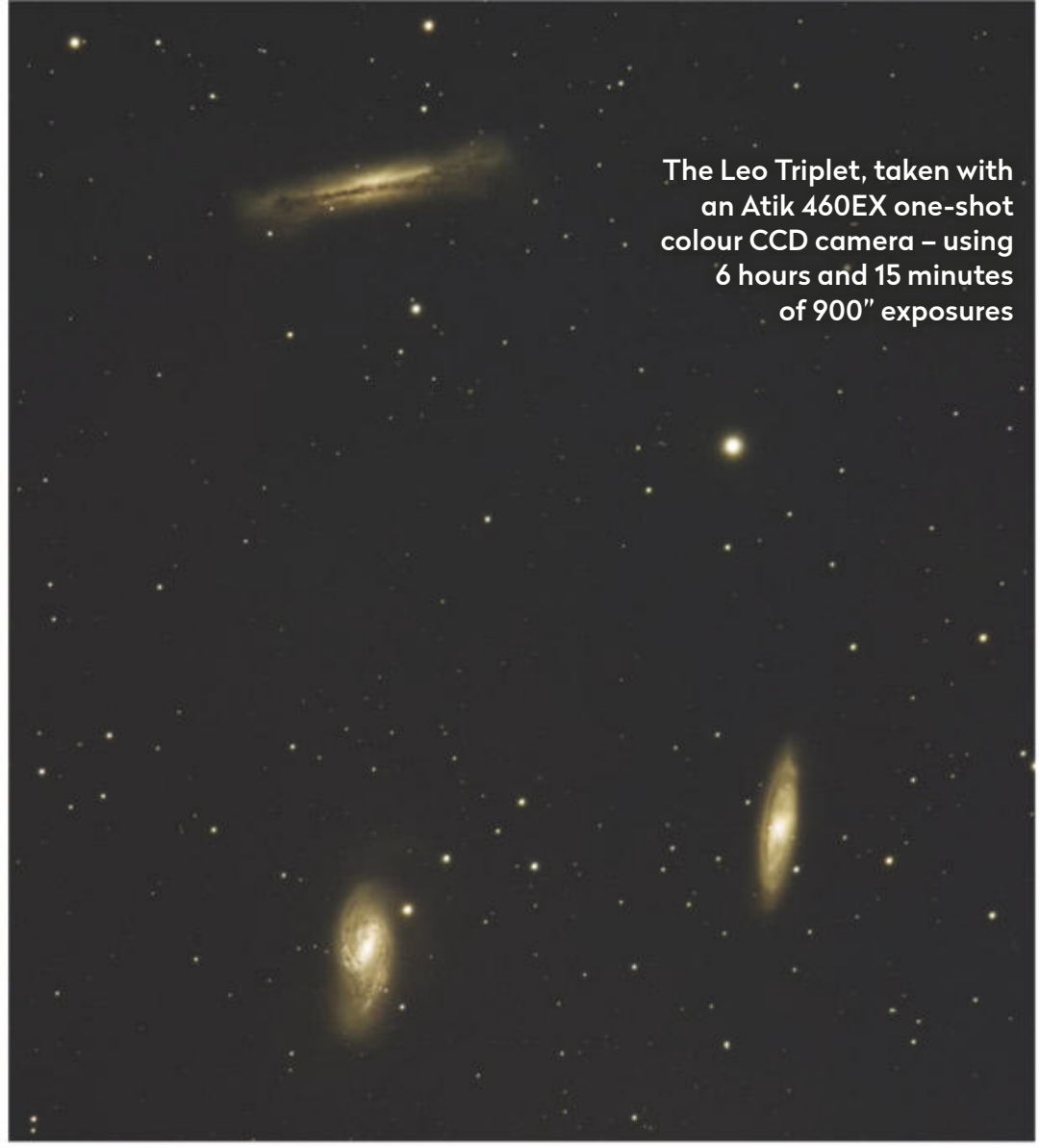
Internal baffles

Inside the tube, behind the lens there are a series of rings, or baffles, that increase in thickness towards the focuser. These add stability to the tube, but their primary role is to reduce the amount of stray or unwanted light inside the tube that can reduce contrast at the eyepiece or camera.

▸ tweak the image back into perfect focus, which again was quick and simple to do accurately.

Our targets of choice were the spiral galaxy M106, the Leo Triplet consisting of M65, M66 and NGC 3628, and the rather comically named Whale and Hockey Stick Galaxies (NGC 4631 and NGC 4656), along with a few other favourites. In total we spent around 20 hours using the ASCENT 115 ED for imaging, and it performed exactly as we hoped, being free of fuss and drama. By that we mean there were no issues with odd star shapes, no unwanted reflections, no dew on the objective lens and no loss of focus during long exposures; in short, it was just what we'd look for in an imaging scope, being easy to use and very capable.

We were also keen to use the ASCENT 115 ED with our eyepieces, and as the increasing brightness of the Moon made galaxy work impossible, we first turned to some lunar exploration. The compact size of the telescope makes for very comfortable viewing positions, and we found this allowed us to take our time on the features, enjoying sharp views of shadows from central peaks across crater floors and wispy bright crater edges seemingly floating around the terminator. Later in the review period we had a short window before moonrise to enjoy some galaxies too, with a particular favourite being the combination of Bode's Galaxy and the Cigar, M81 and M82. Our 13mm eyepiece offered 60x magnification, and this pair looked glorious within the same field of view. An opportunity for solar viewing presented itself, and we used our white light filter to enjoy the sight of a chain of sunspots.



The Leo Triplet, taken with an Atik 460EX one-shot colour CCD camera – using 6 hours and 15 minutes of 900" exposures

◂ The Dumbbell Nebula, M27, taken with the same setup – using 2 hours and 20 minutes of 600" exposures

◂ M106, taken with the same setup – using 1 hour and 30 minutes of 900" exposures

Reasonably priced towards the middle of the market, the combination of aperture, optical quality and focal length in the ASCENT 115 ED provides a happy balance that make it suitable for all-round astronomical pursuits.

VERDICT

Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★★
Imaging quality	★★★★½
Optics	★★★★★
OVERALL	★★★★½

KIT TO ADD

1. 0.8x reducer for ASCENT 115 ED

2. Altair MG60 guidescope

3. Altair Hypercam 61CFX camera

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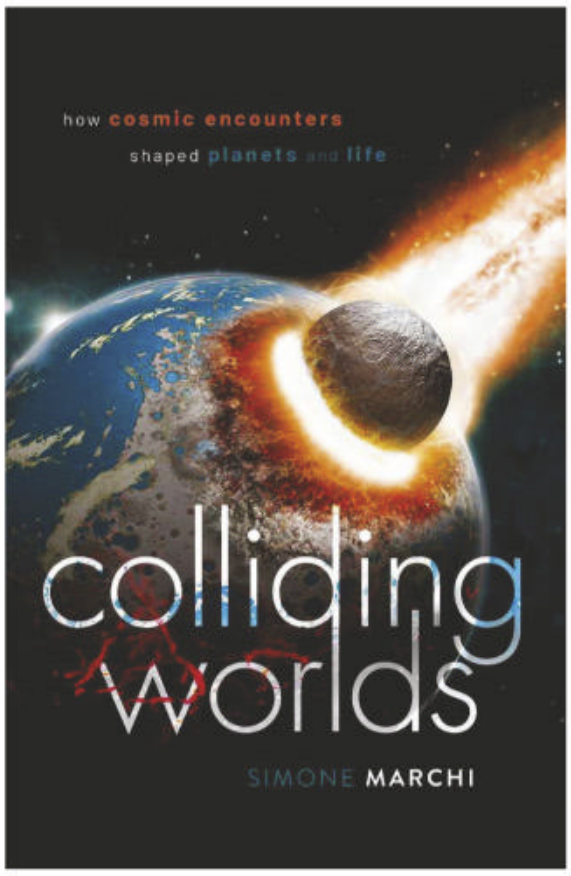
BOOKS



Colliding Worlds

Simone Marchi
Oxford University Press
£20 ● HB

The formation of planets is often glossed over in popular science, not because it's uninteresting, but because our understanding of its detail has only developed relatively recently. In *Colliding Worlds*, Simone Marchi explores this most tumultuous period in the Solar System's history. Along the way we learn more about – as the book's subtitle suggests – "how cosmic encounters shaped planets and life".

This is clearly a book written by an expert in the field, with a few mentions of the author's own research where relevant. There is good depth of explanation around our current understanding, describing subtle areas of disagreement between competing theories. While technical terms are generally explained clearly and concisely, there's no shying away from relatively complex arguments.

The book has a relatively narrow focus on the inner Solar System and collisions of rocky bodies, but this is a strength as it allows depth. It starts with the birth of our Solar System and its planets, moons and other objects. Moving through time, it covers the changes in the major planets' orbits (the only real foray into the outer Solar System) and the origin of objects in the asteroid belt. After a focus on the histories of Earth and Mars, it explores the impact of collisions on the evolution of life on Earth, and what that might imply for the existence of life in other systems.

There's a good deal of discussion of the evidence (some very recent) gained from observations and simulations, sometimes illustrated with high-quality pictures, diagrams and artists' impressions (and the odd graph). Well-trodden topics such as the late heavy bombardment and the dinosaur-killing Chicxulub impact include considered discussions of the possible interpretations, demonstrating there's still lots to learn about this evolving field.

Theories are tested about what caused the Chicxulub impact crater and wiped out the dinosaurs

UGURHAN/ISTOCK/GETTY IMAGES

While the narrative is good, there were times when a change of subject caught me off guard, and I would have welcomed more structure within chapters.

This is an enjoyable read for those interested in learning what we know – and what we don't – about this bit of our history, with lots of titbits for even a well-versed astronomer to pick up. ★★★★★

***Dr Chris North** is Ogden Science Lecturer and STFC Public Engagement Fellow at Cardiff University*

Interview with the author
Simone Marchi

How can we know what the early Solar System was like?

The Moon has lots of impact craters, which tell us that in the early Solar System it was subjected to an intense flux of collisions that shaped the lunar landscape. And we see that not just on the Moon: thanks to space exploration we have visited other planets in the Solar System, other satellites and asteroids. Everywhere we find a rocky surface, we see impact craters. This suggests that in the young Solar System, collision rates were much higher than today.

Why are space rocks of such interest?

Earth and the other planets formed from a disc of debris – smaller asteroids – that accreted over time. As that happened, those objects were altered: pristine materials were transformed and the information they held was lost. The leftovers were small asteroids that still orbit the Sun like Vesta and Ceres, which were not incorporated into larger planets: they kept their primordial properties and today they are key to understanding the formation of the Solar System.

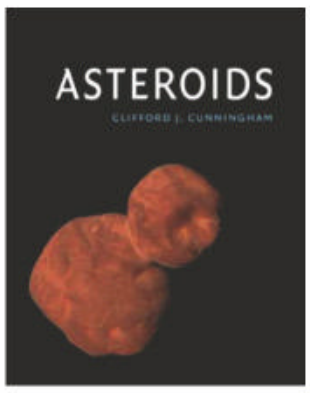
What would a Solar System without collisions be like?

We think of gravity as one of the fundamental forces in physics. It keeps the Solar System together and allows planets to go around the Sun. But there are many other important processes, and collisions are among them. If you could, say, turn off collisions, the Solar System would not exist because planets, asteroids and all that we see, grew as a result of smaller objects coming together and growing in size. If you could turn off that process, we wouldn't be here.

***Simone Marchi** is a planetary scientist at the Southwest Research Institute in Colorado, US*

Asteroids

Clifford J Cunningham
Reaktion
£25 ● HB



With ever-improving technology and methods, we have now identified over a million asteroids and are discovering just how fascinating and varied these objects really are. The largest (and incidentally first discovered, Ceres) is almost 1,000km in diameter, but the term 'asteroid' includes objects down to a few metres across. Some appear bright, while others are dark, and some are dominated by metals, while others appear to harbour vast quantities of water. Most are inactive, but some display comet-like tails as they come near the Sun. While many are solitary objects, some have their own satellites, being binary or ternary systems – and at least one has a ring system.

In *Asteroids*, Clifford J Cunningham provides a historical account of this rapidly growing field, navigating us through the nomenclature used. Later chapters also focus on the role of asteroids in the evolution of our Solar System and their appearance in popular culture. There is also an overview of past, present and future space missions that aim to discover even more by flying past, orbiting and even landing on and returning samples from these celestial bodies. There are also suggestions about ways a reader can become involved in current asteroid research through various ongoing citizen science projects.

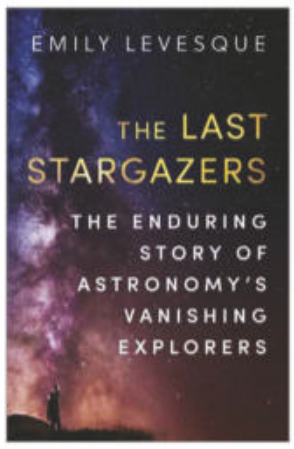
Asteroids is an insightful read, providing an overview of the field in an engaging format that is testament to both the skill and authority of the author. ★★★★★

***Dr Penny Wozniakiewicz** is a lecturer in space science at the University of Kent*

The Last Stargazers

Emily Levesque
Oneworld
£10.99 ● PB

PACKED WITH INSIGHTS



"Yes, but what do you actually do all day?" is a question many professional astronomers are asked on admitting to their chosen career. The answer, to a large extent, can be found in the pages of this book.

Perhaps the first book of its type produced in the modern era, in it the author presents a description of how astronomy is done, but skilfully avoids being a dry technical exposé. Partly autobiographical, *The Last Stargazers* also draws on the human experiences and personal stories of a vast group of contemporary astronomers. The result is an insightful view of the daily (and often nightly) regime of the modern observational astronomer. The passion, adventure, challenge, humour and, yes, danger, in the pursuit of knowledge are palpably brought to life.

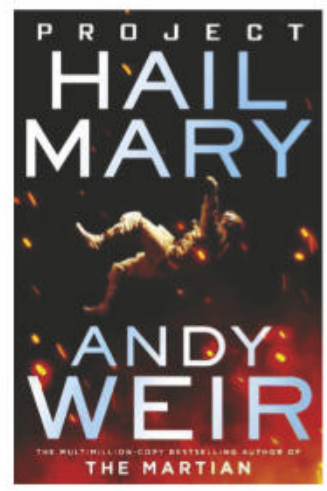
As a backdrop to this wonderful human story the reader will gather much about the technological advances of recent decades. We are taken from an era when astronomers actually looked through a telescope, at times strapped precariously to vast mechanisms in the cold and dark, to the often stark, decidedly unadventurous and detached reality of remote, robotic or 'queue' observing seen today.

For the professional astronomer, the personal experiences lovingly documented in this book will evoke many pleasant memories. But it is also a must-read for the uninitiated, the armchair stargazer, or anyone contemplating a career in astronomical research: a funny, romantic, intriguing real-life adventure. ★★★★★

***Dr Alastair Gunn** is a radio astronomer at Jodrell Bank Observatory in Cheshire*

Project Hail Mary

Andy Weir
Del Rey
£16.99 ● HB



Ryland Grace awakes alone on a spacecraft with no memory of how he got there, knowing only that his mission is to save Earth from an ice age brought about by alien life slowly but surely consuming the energy of the Sun.

It is the story that most science-fiction novels boil down to – perhaps bar the Sun-sucking microbes: of one man on a mission to save the world, but *Project Hail Mary* still manages to feel unique. This is a book about sacrifice, friendship, and boring, cowardly people doing what they must to help others in the face of impossible decisions. Given our own ongoing global crisis, it is incredibly timely.

As with Andy Weir's previous book *The Martian* (2011), there is plenty of obscure science detail packed into the story. We discover how to calculate mass in zero-g, how aliens might survive without water, and the most painless way to die in space – to name just a few examples.

At times the level of detail has a tendency to stray from being well-researched to being relatively uninteresting, and the characters can feel a little two-dimensional at times, occasionally relying on national stereotypes in place of character development.

However, after an initial slow start the pacing really picks up and by the end of the book I was crying buckets and desperate for a sequel. The story twists and turns in unpredictable ways, making this a delightfully compulsive read, impossible to stop thinking about, and one any fan of science-fiction will treasure. One small warning: if you have terrible arachnophobia, brace yourself! ★★★★½

***Katie Sawers** is a science writer specialising in cosmology and astronomy history*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Celestron lens cleaning kit

Price £14.99 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

Safely remove dust, dirt and fingerprints from your optics with this cleaning kit. It comes with a bottle of cleaning solution, a lens brush, a cleaning cloth and 10 lens wipes, all in a convenient carry pouch.

2 Altair 100mm ultra-light guidescope rings

Price £99.50 • **Supplier** Altair Astro
Tel 01263 731505 • **www.altairastro.com**

The design of these rings means they can maintain a secure grip on your guidescope and remain lightweight. The anodised, stainless steel components will also leave your setup rust-free, and will fit guidescopes with an outer diameter between 45mm and 80mm.

3 Mars exploration crew jacket

Price £120 • **Supplier** Science Museum
https://shop.sciencemuseum.org.uk

Prepare for launch and get ready for Mars with this crew jacket. The orange fabric brings to mind the flight suits of Shuttle-era NASA astronauts, while the selection of patches lets the world know where your mission is bound. Available in a variety of sizes.

4 Pegasus astro battery couplers

Price £17.50 • **Supplier** Widescreen Centre
Tel 01353 776199 • **www.widescreen-centre.co.uk**

Get rid of the batteries and hook your DSLR straight up to the mains with this device. The adaptor creates a stable power source that lets your camera operate all night, which is great for an observatory setup.

5 Lego NASA Space Shuttle Discovery

Price £169.99 • **Supplier** Lego
Tel 0800 5346 5555 • **www.lego.com**

Recreate Space Shuttle Discovery's deployment of the Hubble Space Telescope with this 2,354-piece Lego kit. Its moveable payload doors, robot arm and solar panels, as well as Hubble itself, give you plenty of choice in how you present your finished model.

6 Vixen protective bag for 8-inch telescopes

Price £143 • **Supplier** Telescope House
Tel 01342 837098 • **www.telescopehouse.com**

Protect your telescope from dirt, shocks and vibrations while transporting with this padded carry bag. Comes with three additional accessory bags, and fits scopes up to 700mm in length and 232mm in diameter.

Paul F Cockburn interviews Professor Catherine Heymans

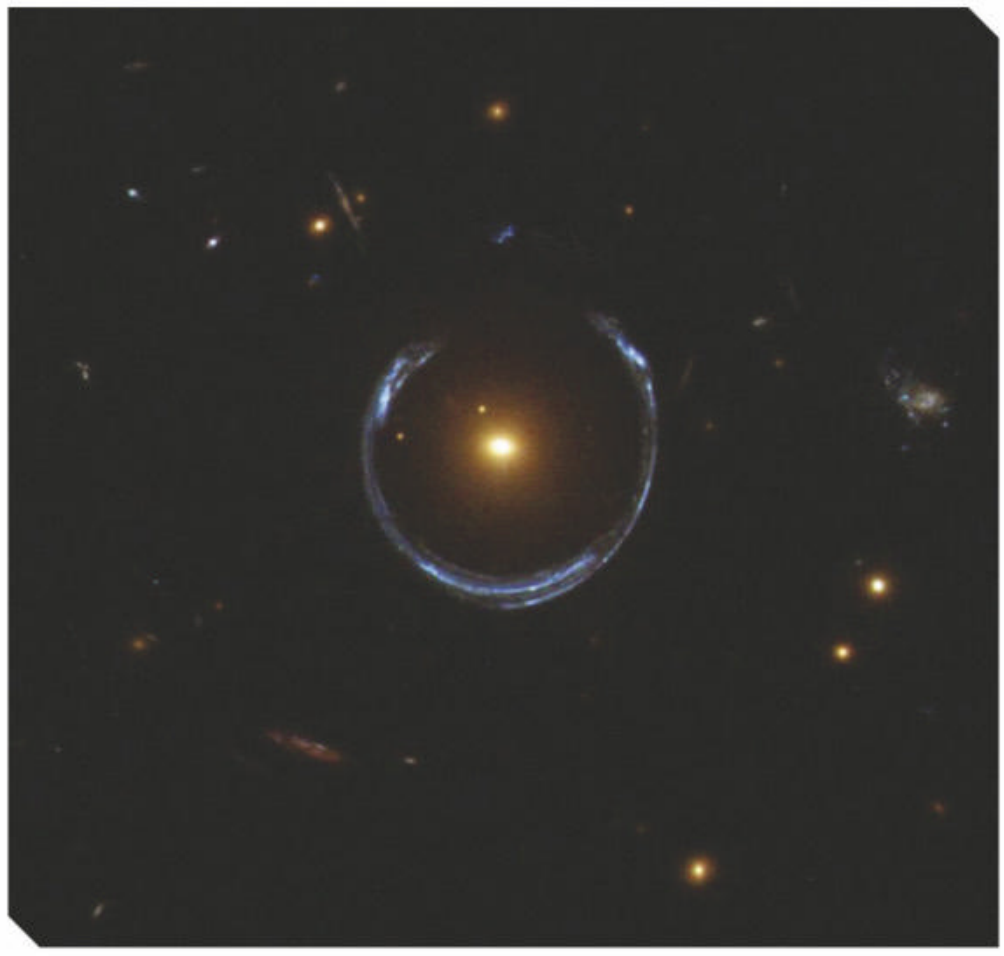
Q&A WITH THE NEW ASTRONOMER ROYAL FOR SCOTLAND

An internationally recognised expert on the 'dark universe' – dark energy and dark matter – is ready to share her passion for astronomy with the public

The Astronomer Royal for Scotland role goes back to 1834. How were you appointed?
After [the previous holder] John Brown sadly passed away in 2019, the Scottish Universities Physics Alliance, a network of all the Physics Departments in Scotland, started talking about it. Then they involved the Royal Society of Edinburgh, who convened an international panel. They looked at all of the astronomers in Scotland, created a shortlist and contacted all of us to ask if this was something we would be interested in. I wrote back saying, "Of course!" And put together a "vision document" of what I'd like the role to be. I guess the panel liked my vision, because they asked if would I like to be recommended to The Queen? I said yes, and the Queen wrote back saying she was happy with the recommendation, so there we go.

How do you see your new role developing?
Well, the job description is blank. It's really exciting for me to be able to say what I think the job will be. Also, I'm reaching out to all of the amateur astronomers and professional astronomers in Scotland and across the UK to ask what they want the Astronomer Royal for Scotland to do. There are so many fantastic ideas out there, so many passionate people: our amateur astronomy groups across the UK have grown in size immensely over lockdown. Because we couldn't explore geographically, people instead started looking up and out into the Universe – so, let's capitalise on that.

How important is it to you to be the first woman to take on this role?
I've had so many lovely emails from people just saying how important it is to them to see this role – which has always been held by men – finally being held by a woman. It shows that female astronomers are out there. We exist! I'm the 11th Astronomer Royal for Scotland; that's one out of 11. If you look at the percentage of female professors in physics, it's about that ratio as well. There's this cultural perception that physics is not for girls, and the more visible women we can have out there, the better.



ESA/HUBBLE & NASA

▲ **Catherine looked at the gravitational effects of dark matter during her PhD, and how it's changing over time**

Catherine Heymans is Professor of Astrophysics at the University of Edinburgh and the first female Astronomer Royal for Scotland

What attracted you to the 'dark universe'?
During my undergraduate course in physics at the University of Edinburgh, we were getting a bit bogged down in it, and our lecturer said: "Let's just take a break, because a really exciting scientific paper has come out today." He took us through Adam Riess's first evidence that the expansion of the Universe is actually accelerating. We came out of that lecture absolutely buzzing. I just thought: Yeah, I want to do a PhD to solve what this dark energy is. Honestly, how naive!

It didn't quite work out then...
My PhD was on gravitational lensing, which you can use to look at the gravitational effects of dark matter, how it's changing over time and how that tells you what the dark energy is doing. I didn't solve dark matter and dark energy, of course, but my PhD was setting the groundwork for how you actually make these measurements. It's really very meticulous work, because the distortions you're looking for in the data are at the level of about 1 per cent.

How will you balance your new responsibilities as Astronomer Royal for Scotland?
My research has been funded by taxpayers throughout my whole life, so I have always been a keen science communicator. I'm not going to stop the day job with the research because I haven't solved it. I was clearly naive thinking that I would solve it during my PhD, but I'm hopeful that, by the time I retire, we'll have worked this one out. I'm very lucky that the University of Edinburgh really wants to see me doing something with this role as well, so they are giving me a bit of time to do it.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch Mars and Venus together in the evening sky, and enjoy the Milky Way's starry multitude

When to use this chart

1 July at 00:00 AEST (14:00 UT)
15 July at 23:00 AEST (13:00 UT)
31 July at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JULY HIGHLIGHTS

To catch a dance between Venus and Mars, try looking one hour after sunset in the early evening sky. Venus passes Mars on the 13th, when they appear just 0.5° apart. The night before (the 12th) sees the thin crescent Moon 4.5° below the pair. Fortunately, the glare of Venus makes it easy to tell the planets apart. The 'goddess of love' outruns Mars, passing Regulus (Alpha (α) Leonis) on the 22nd (1.0° apart), with Mars passing the same star on the 30th, slightly closer.

STARS AND CONSTELLATIONS

With the Milky Way's centre passing overhead in mid evenings this month, it is a wonderful time to explore our home Galaxy. Some of the most prominent landmarks are visible; look up to see the Teapot of Sagittarius and the constellation of Scorpius. Still recognisable, but on its side, is the Southern Cross (Crux) and its two pointers in the southwest.

To view the Milky Way's glow, made of billions of distant stars and its dark lanes, you will need to escape to the country.

THE PLANETS

As mentioned above, the early northwest twilight sky belongs to Venus and Mars. Next to arrive is Saturn and then Jupiter, with both gas giants visible up in the eastern sky by mid evening and transiting (due north) in the early morning. The morning sees the outermost planets visible, with Neptune well up by midnight and Uranus at its best around an hour before dawn. Early in July, Mercury can be seen low in the northeast dawn sky, dropping out of sight in the third week.

DEEP-SKY OBJECTS

The hub of our Galaxy is home to many globular clusters. There's a couple of brilliant examples, M62 and M19, tucked into the southwest corner of the constellation of Ophiuchus, the Serpent-bearer, 8° eastward of Antares (Alpha (α) Scorpii). The bright, 6th magnitude pair made it into Charles Messier's catalogue.

Both are visible in the same binocular field; M62 (RA 17h 01.2m, dec. -30° 07') consists of a circular 7' halo, with a bright core offset to the south, while M19 (RA 17h 02.6m, dec. -26° 16') is only 4° north of M62.

M19 is smaller than M62 and has a distinctly oval halo (6'x4') with more diffuse stars at the southern end. Its brightness rises to a similar shaped core (3'x2'), which is off-centre to the north.

The view is improved greatly through larger-sized telescopes (20cm-plus) with mottling, bright knots and numerous scattered stars just resolved.

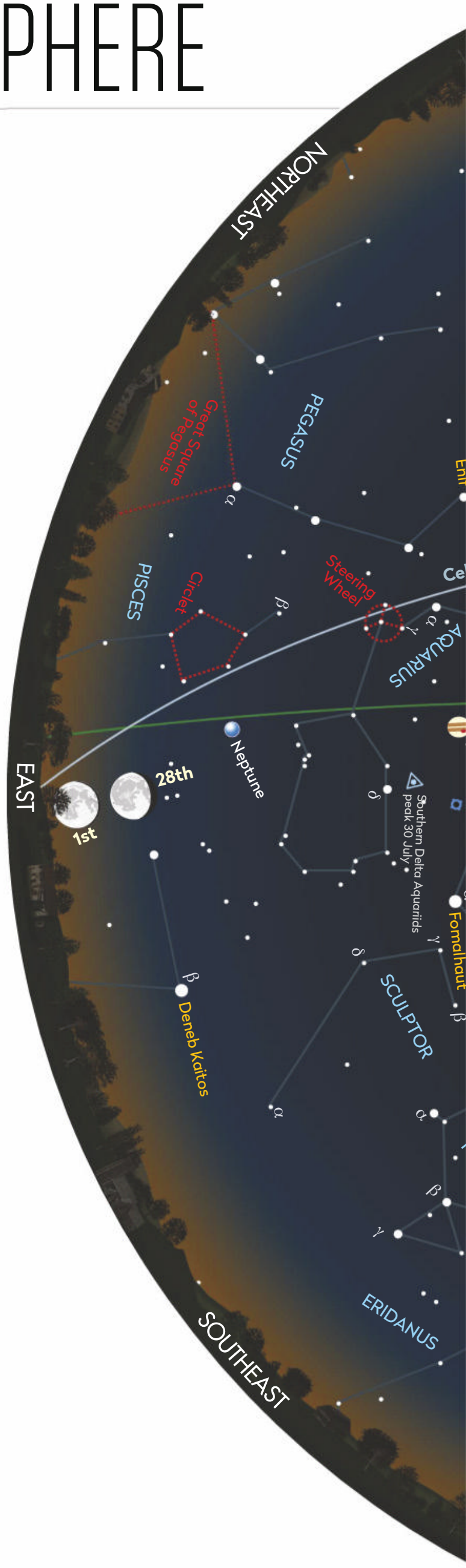

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
DRACO
HERCULES
M92
Keystone
M13
CORONA BOREALIS
BOÖTES
Arcturus
Kite
Denebola
Denebola
NGC 7000
CYGNUS
Summer Triangle
LYRA
Vega
M29
Northern Cross
Albireo
M57
Veil Nebula
VULPECULA
M27
M71
Collinder 399
DELPHINUS
SAGITTA
Rasalgethi
Rasalhague
Altair
AQUILA
M15
EQUULEUS
IC 4665
OPHIUCHUS
SERPENS CAPUT
Celestial Equator
SERPENS CAUDA
M14
M10
M12
M5
Coffin
M2
NGC 7009
Alpha Capricornids peak 30 July
M11
SCUTUM
M17
M25
M107
M9
M8
Ecliptic
M75
Pluto
Saturn
Jupiter
25th
22nd
19th
16th
LIBRA
VIRGO
Spica
M19
M62
M6
M7
Teapot
Antares
HN 28
M55
M30
CAPRICORNUS
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
SCORPIUS
NORMA
LUPUS
Piscis Austrinids peak 28 July
PISCIS AUSTRINUS
GRUS
INDUS
ARA
CORVUS
PAVO
TRIANGULUM AUSTRALE
Rigel Kentaurus
W Cen
CENTAURUS
HYDRA
M68
TUCANA
CIRCINUS
OCTANS
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PHOENIX
47 Tuc
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NGC 4755 Jewel Box
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MUSCA
IC 2944
Colinder 240
NGC 3532
Achernar
HYDRUS
CHAMAELEON
South Celestial Pole
Southern Pleiades
CARINA
Eta Carina Neb
Miaplacidus
MENSA
RETICULUM
LMC
NGC 2070
VOLANS
VELA
ANTLIA
False Cross
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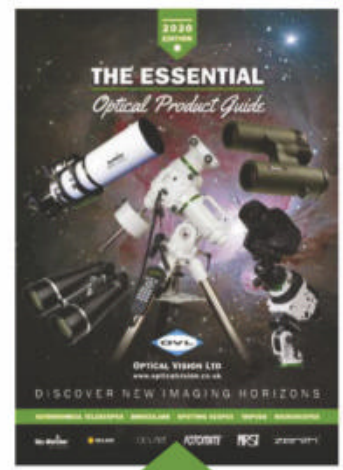

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